REPORT

OF THE

TENTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT GLASGOW IN AUGUST 1840.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1841.

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OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other Institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

MEMBERS.

All Persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Members of the Association, subject to the approval of a General Meeting.

SUBSCRIPTIONS.

The amount of the Annual Subscription shall be One Pound, to be paid in advance upon admission; and the amount of the composition in lieu thereof, Five Pounds.

An admission fee of One Pound is required from all Members elected as Annual Subscribers, after the Meeting of 1839, in addition to their annual subscription of One Pound.

Members are entitled to receive copies of any volume of the Transactions for two-thirds of the price at which it is sold to the public; or by one present payment of Five Pounds, as a fixed *Book Subscription*, to receive a copy of all the volumes of Transactions published after the date of such payment.

Subscriptions shall be received by the Treasurer or Secretaries.

If the annual subscription of any Member shall have been in arrear for two years, and shall not be paid on proper notice, he shall cease to be a Member.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.
2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.
3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.
4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.
5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the meeting of the year by the President and General Secretaries.
6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee, unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

OFFICERS AND COUNCIL, 1840–41.

Trustees (permanent).—Francis Baily, Esq. R. I. Murchison, Esq. John Taylor, Esq.

President.—The Most Noble the Marquis of Breadalbane.

Vice-Presidents.—The Very Reverend Principal Macfarlane. Major-Gen. Lord Greenock. Sir David Brewster. Sir Thos. Macdougall Brisbane.

President elect.—Rev. Professor Whewell, F.R.S., V.P.G.S.

Vice-Presidents elect.—The Earl of Mount Edgcumbe. The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart., M.P. Sir T. D. Acland, Bart., M.P.

General Secretaries.—R. I. Murchison, Esq., F.R.S. Major Sabine, F.R.S.

Assistant General Secretary.—John Phillips, Esq., F.R.S., York.

Secretaries for the Plymouth, Devonport, and Stonehouse Meeting in 1841.—Wm. Snow Harris, F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, F.R.S. Richard Taylor, jun., Esq.

General Treasurer.—John Taylor, Esq., F.R.S., &c. 2, Duke Street, Adelphi, London.

Treasurer to the Meeting in 1841.—Henry Woolcombe, Esq.

Council.—Dr. N. Arnott. R. Brown, Esq. Rev. Dr. Buckland. J. C. Colquhoun, Esq., M.P. Dr. Daubeny. Sir P. G. Egerton, Bart., M.P. Professor T. Graham. J. E. Gray, Esq. G. B. Greenough, Esq. W. J. Hamilton, Esq. Dr. Hodgkin. R. Hutton, Esq., M.P. H. B. Jerrard, Esq. C. Lyell, Esq. Professor Miller. Professor Moseley. The Marquis of Northampton. The Very Rev. Dr. Peacock. E. Pendarves, Esq., M.P. Professor Powell. Lord Sandon, M.P. H. E. Strickland, Esq. Lieut.-Col. Sykes. H. Fox Talbot, Esq. N. A. Vigors, Esq., M.P. James Walker, Esq. Captain Washington. Professor Wheatstone.

Secretary to the Council.—James Yates, Esq., F.R.S. 49, Upper Bedford Place, London.

Local Treasurers.—Dr. Daubeny, Oxford. Professor Henslow, Cambridge. Dr. Orpen, Dublin. Charles Forbes, Esq., Edinburgh and Glasgow. William Gray, jun., Esq., York. William Sanders, Esq., Bristol. Samuel Turner, Esq., Liverpool. Rev. John James Tayler, Manchester. James Russell, Esq., Birmingham. William Hutton, Esq., Newcastle-on-Tyne. Henry Woolcombe, Esq., Plymouth.

I. Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

Presidents.	Vice-Presidents.	Local Secretaries.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.SS.L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
Sir T. MACDOUGAL BRISBANE, K.C.B., D.C.L., F.R.SS.L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.SS.L. & E., &c. Sir John Robison, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chan. Univ. Lon. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S.	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MOST NOBLE THE MARQUIS OF BREADALBANE. GLASGOW, September 17, 1840.	Very Rev. Principal Macfarlane Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July ~~[illegible]~~, 1841. 29	The Earl of Mount Edgcumbe The Earl of Morley Lord Eliot, M.P. Sir C. Lemon, Bart., M.P. Sir T. D. Acland, Bart., M.P.	Wm. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, F.R.S. Richard Taylor, jun., Esq.

II. Table showing the Members of Council of the British Association from its Commencement, in addition to Presidents, Vice-Presidents, and Local Secretaries.

General Secretaries.	Rev. Wm. Vernon Harcourt, F.R.S., &c.	1832—1836.
	Francis Baily, V.P. and Treas. R.S.	1835.
	R. I. Murchison, F.R.S., F.G.S.	1836—1840.
	Rev. G. Peacock, F.R.S., F.G.S., &c.	1837, 1838.
	Major Sabine, V.P.R.S.	1839, 1840.
General Treasurer.	John Taylor, F.R.S., Treas. G.S., &c.	1832—1839.
Trustees (permanent).	Charles Babbage, F.R.SS.L. & E., &c.	(Resigned.)
	R. I. Murchison, F.R.S., &c.	
	John Taylor, F.R.S., &c.	
	Francis Baily, F.R.S.	
Assistant General Secretary.	Professor Phillips, F.R.S., &c.	1832—1839.

Members of Council.

G. B. Airy, F.R.S., Astronomer Royal ......1834, 1835.
Neill Arnott, M.D. ....1838, 1839, 1840.
Francis Baily, V.P. and Treas. R.S. ....1837—1839.
George Bentham, F.L.S. ....1834, 1835.
Robert Brown, D.C.L., F.R.S. ....1832, 1834, 1835, 1838-1840.
Sir David Brewster, F.R.S., &c. ....1832.
M. I. Brunel, F.R.S., &c. ....1832.
Rev. Professor Buckland, D.D., F.R.S., &c. .1833, 1835, 1838, 1839, 1840.
The Earl of Burlington .... 1838, 1839.
Rev. T. Chalmers, D.D., Prof. of Divinity, Edinburgh ....1833.
Professor Clark, Cambridge ....1838.
Professor Christie, F.R.S., &c....................1833—1837.
William Clift, F.R.S., F.G.S. ....1832—1835.
J. C. Colquhoun, Esq., M.P. ....1840.
John Corrie, F.R.S., &c. ....1832.
Professor Daniell, F.R.S. ....1836, 1839.
Dr. Daubeny.............. ....1838, 1839, 1840.
J. E. Drinkwater ....1834, 1835.
Sir P. G. Egerton, Bart., M.P....... ....1840.
The Earl Fitzwilliam, D.C.L., F.R.S., &c....1833.
Professor Forbes, F.R.SS.L. & E., &c. ......1832.
Davies Gilbert, D.C.L., V.P.R.S., &c. ......1832.
Professor R. Graham, M.D., F.R.S.E.........1837.
Professor Thomas Graham, F.R.S. ....1838, 1839, 1840.
John Edward Gray, F.R.S., F.L.S., &c.......1837—1839, 1840.
Professor Green, F.R.S., F.G.S. ....1832.
G. B. Greenough, F.R.S., F.G.S. ....1832—1839, 1840.
Henry Hallam, F.R.S., F.S.A., &c............1836.
Sir William R. Hamilton, Astron. Royal of Ireland ....1832, 1833, 1836.
W. J. Hamilton, Sec. G.S. ....1840.
Rev. Prof. Henslow, M.A., F.L.S., F.G.S....1837.
Sir John F. W. Herschel, F.R.SS. L. &. E., F.R.A.S., F.G.S., &c. ....1832.
Thomas Hodgkin, M.D. ....1833—1837, 1839, 1840.
Prof. Sir W. J. Hooker, LL.D., F.R.S., &c. .1832.

Rev. F. W. Hope, M.A., F.L.S. ....1837.
Robert Hutton, M.P., F.G.S., &c. ....1836, 1838, 1839, 1840.
Professor R. Jameson, F.R.SS. L. & E. ....1833.
Rev. Leonard Jenyns .. ..1838.
H. B. Jerrard, Esq. ....1840.
Dr. R. Lee...1839.
Sir C. Lemon, Bart., M.P. ....1838, 1839.
Rev. Dr. Lardner.................................1838, 1839.
Professor Lindley, F.R.S., F.L.S., &c. ......1833, 1836.
Rev. Professor Lloyd, D.D......................1832, 1833.
J. W. Lubbock, F.R.S., F.L.S., &c., Vice-
Chancellor of the University of London 1833—1836, 1838, 1839.
Rev. Thomas Luby ....1832.
Charles Lyell, jun., F.R.S. ....1838, 1839, 1840.
William Sharp MacLeay, F.L.S. ....1837.
Professor Miller, F.G.S.........................1840.
Professor Moseley ....1839, 1840.
Patrick Neill, LL.D., F.R.S.E. ....1833.
The Marquis of Northampton, P.R.S. ....1840.
Richard Owen, F.R.S., F.L.S.....................1836, 1838, 1839.
Rev. George Peacock, M.A., F.R.S., &c......1832, 1834, 1835, 1839, 1840.
E. Pendarves, Esq., M.P.........................1840.
Rev. Professor Powell, M.A., F.R.S., &c......1836, 1837, 1839, 1840.
J. C. Prichard, M.D., F.R.S., &c................1832.
George Rennie, F.R.S. ....1833—1835, 1839.
Sir John Rennie....................................1838.
Rev. Professor Ritchie, F.R.S. ....1833.
Sir John Robison, Sec. R.S.E. ....1832, 1836.
P. M. Roget, M.D., Sec. R.S., F.G.S., &c....1834—1837.
Major Sabine ....1838.
Lord Sandon, M.P..................................1840.
Rev. William Scoresby, B.D., F.R.SS. L. & E.1832.
H. E. Strickland, Esq., F.G.S....................1840.
Lieut.-Col. W. H. Sykes, F.R.S., F.L.S., &c. 1837—1839, 1840.
H. Fox Talbot, Esq., F.R.S. ....1840.
Rev. J. J. Tayler, B.A., Manchester............1832.
Professor Traill, M.D. ....1832, 1833.
N. A. Vigors, M.P., D.C.L., F.S.A., F.L.S... 1832, 1836, 1840.
James Walker, Esq., P.S.C.E.......................1840.
Captain Washington, R.N..........................1838, 1839, 1840.
Professor Wheatstone ....1838, 1839, 1840.
Rev. W. Whewell...................................1838, 1839.
William Yarrell, F.L.S. ....1833—1836.

Secretaries to the Council. { Edward Turner, M.D., F.R.SS. L. & E. 1832—1836.
James Yates, F.R.S., F.L.S., F.G.S. 1831—1840.

OFFICERS OF SECTIONAL COMMITTEES AT THE GLASGOW MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Professor Forbes, F.R.S.

Vice-Presidents.—G. B. Airy, Esq., F.R.S., Astron. Royal. Rev. Professor Whewell, F.R.S. Professor James Thomson, LL.D.

Secretaries.—Professor Stevelly. Rev. Dr. Forbes, F.R.S. Arch. Smith, Esq.

SECTION B.—CHEMISTRY AND MINERALOGY.

President.—Dr. Thomas Thomson, F.R.S.

Vice-Presidents.—Professor Thomas Graham, F.R.S. Professor Johnston, F.R.S.

Secretaries.—Dr. R. D. Thomson. Dr. Thomas Clark. Dr. L. Playfair.

SECTION C.—GEOLOGY AND PHYSICAL GEOGRAPHY.

President for Geology.—Charles Lyell, Esq., F.R.S.

President for Physical Geography.—G. B. Greenough, Esq., F.R.S.

Vice-Presidents.—Rev. Professor Buckland, F.R.S. H. T. De la Beche, Esq., F.R.S. James Smith, Esq., F.R.S. Capt. Washington, R.N.

Secretaries.—W. J. Hamilton, Esq., F.R.S. H. E. Strickland, Esq., F.G.S. D. Milne, Esq., F.G.S. John Scoular, Esq., M.D. Hugh Murray, Esq., F.R.S.E.

SECTION D.—ZOOLOGY AND BOTANY.

President.—Sir W. J. Hooker, LL.D.

Vice-Presidents.—The Rev. Professor Fleming, D.D. Sir William Jardine, Bart. Professor Graham, F.R.S.E. P. J. Selby, Esq., F.L.S.

Secretaries.—Professor William Couper. Robert Paterson, Esq. Edward Forbes, Esq., M.W.S.

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Vice-Presidents.—J. Hodgkin, Esq , M.D. Dr. Andrew Buchanan. Dr. John M'Farlane.

Secretaries.—Professor Couper. Dr. James Brown. Professor Reid.

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President.—Lord Sandon, F.R.S., M.P.

Vice-Presidents.—Mr. Sheriff Alison. Rev. Dr. Chalmers. Lieutenant-Colonel Sykes, F.R.S.

Secretaries.—Professor Ramsay. R.W. Rawson, Esq. Charles R. Baird, Esq.

SECTION G.—MECHANICAL SCIENCE.

President.—Sir John Robison, Sec. R.S. Edin.

Vice-Presidents.—His Grace the Duke of Argyll. The Rev. T. R. Robinson, D.D. John Taylor, Esq., Treas. B.A. James Walker, Esq., Pres. Inst. Civ. Eng.

Secretaries.—J. Scott Russell, Esq. Charles Vignoles, Esq., C.E. James Thompson, Esq., C.E. James Tod, Esq., Sec. Soc. of Arts.

CORRESPONDING MEMBERS.

Professor Agassiz, Neufchatel. M. Arago, Secretary of the Institute, Paris. A. Bache, Principal of Girard College, Philadelphia. Professor Berzelius, Stockholm. Professor De la Rive, Geneva. Professor Dumas, Paris. Professor Ehrenberg, Berlin. Professor Encke, Berlin. Baron Alexander von Humboldt, Berlin. M. Jacobi, St. Petersburgh. Professor Liebig, Giessen. Professor Link, Berlin. Professor Œrsted, Copenhagen. M. Otto, Breslau. Jean Plana, Astronomer Royal, Turin. M. Quetelet, Brussels. Professor Schumacher, Altona.

TREASURER'S ACCOUNT from

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in hand from last year's Account				460	13	4
Compositions from Members at the Birmingham Meeting and since	512	0	0			
Subscriptions, 1839	1023	1	0			
Ditto 1840	2	0	0			
Ditto Arrears 1838	18	1	0			
				1555	2	0
Dividend on £5500 in 3 per cent. consols, 6 months to January 1840	82	10	0			
Ditto £5000 ditto 6 months to July last	75	0	0			
				157	10	0
Received on account of Sale of Reports, viz.						
1st vol., 2nd Edition	16	14	0			
2nd vol.	12	16	0			
3rd vol.	17	10	0			
4th vol.	26	2	0			
5th vol.	27	4	0			
6th vol.	83	6	0			
7th vol.	160	15	0			
				344	7	0
Lithographs sold				1	10	0
Dublin Report sold				0	2	3
Compositions for future publications				75	0	0
Sale of £500 3 per cent. consols				460	13	6
				£3054	18	1

W. H. SYKES,
LEONARD HORNER,
WILLIAM YARRELL, } Auditors.

16th August 1839 to the 31st August 1840.

PAYMENTS.

	£	s.	d.	£	s.	d.
Expenses of Meeting at Birmingham				250	0	0
Disbursements by General and Local Treasurers				103	11	1
Salaries to Assistant Secretary, Accountant and Clerk				247	10	0
Grants to Committees for Scientific purposes, viz. for						
Reduction of Stars in Histoire Céleste	242	10	0			
Do. do. Lacaille	4	15	0			
Catalogue do.	264	0	0			
Tides' Discussions at Bristol, 1838.	100	0	0			
Do. do.	50	0	0			
Subterranean Temperature	13	13	6			
Land and Sea Level 1838	6	11	1			
Atmospheric Air	15	15	0			
Action of Water on Iron	10	0	0			
Do on Organic matter	7	0	0			
Foreign Scientific Memoirs, 1838. £100 0 0; Do. do. 1839. 12 1 6	112	1	6			
Working Population, 1838	100	0	0			
School Statistics, 1838	50	0	0			
Forms of Vessels, 1838	184	7	0			
Meteorological Observations at Plymouth	40	0	0			
Mr. Osler's Anemometer do.	30	0	0			
Professor Whewell's do. do.	10	0	0			
Meteorological Observations in Scotland (Hourly)	52	17	6			
Magnetical Observations (Instruments)	185	13	9			
Chemical and Electrical Phænomena	40	0	0			
Experiments on the Heart	18	19	0			
Do. Lungs	8	13	0			
Reduction of Meteorological Observations	1	8	0			
				1548	4	4
Paid for Printing Reports, 7th vol	447	15	0			
Do. Engraving for do.	74	4	6			
				521	19	6
Printing List of Members				31	0	2
Do. and Advertising, &c				20	9	6
Sundry Expenses in Publishing Reports				22	12	0
Balance in hands of Bankers	205	17	0			
Do. Treasurer and Local Treasurers	103	14	6			
				309	11	6
				£3054	18	1

The following Reports on the Progress and Desiderata of different branches of Science have been drawn up at the request of the Association, and printed in its Transactions.

1831–32.

On the progress of Astronomy during the present century, by G. B. Airy, M.A., Astronomer Royal.

On the state of our knowledge respecting Tides, by J. W. Lubbock, M.A., Vice-President of the Royal Society.

On the recent progress and present state of Meteorology, by James D. Forbes, F.R.S., Professor of Natural Philosophy, Edinburgh.

On the present state of our knowledge of the Science of Radiant Heat, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry, Oxford.

On Thermo-electricity, by the Rev. James Cumming, M.A., F.R.S., Professor of Chemistry, Cambridge.

On the recent progress of Optics, by Sir David Brewster, K.C.G., LL.D., F.R.S., &c.

On the recent progress and present state of Mineralogy, by the Rev. William Whewell, M.A., F.R.S.

On the progress, actual state, and ulterior prospects of Geology, by the Rev. William Conybeare, M.A., F.R.S., V.P.G.S., &c.

On the recent progress and present state of Chemical Science, by J. F. W. Johnston, A.M., Professor of Chemistry, Durham.

On the application of Philological and Physical researches to the History of the Human species, by J. C. Prichard, M.D., F.R.S., &c.

1833.

On the advances which have recently been made in certain branches of Analysis, by the Rev. G. Peacock, M.A., F.R.S., &c.

On the present state of the Analytical Theory of Hydrostatics and Hydrodynamics, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of our knowledge of Hydraulics, considered as a branch of Engineering, by George Rennie, F.R.S., &c. (Parts I. and II.)

On the state of our knowledge respecting the Magnetism of the Earth, by S. H. Christie, M.A., F.R.S., Professor of Mathematics, Woolwich.

On the state of our knowledge of the Strength of Materials, by Peter Barlow, F.R.S.

On the state of our knowledge respecting Mineral Veins, by John Taylor, F.R.S., Treasurer G.S., &c.

On the state of the Physiology of the Nervous System, by William Charles Henry, M.D.

On the recent progress of Physiological Botany, by John Lindley, F.R.S., Professor of Botany in the University of London.

1834.

On the Geology of North America, by H. D. Rogers, F.G.S.

On the philosophy of Contagion, by W. Henry, M.D., F.R.S.

On the state of Physiological Knowledge, by the Rev. Wm. Clark, M.D., F.G.S., Professor of Anatomy, Cambridge.

On the state and progress of Zoology, by the Rev. Leonard Jenyns, M.A., F.L.S., &c.

On the theories of Capillary Attraction, and of the Propagation of Sound as affected by the Development of Heat, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of the science of Physical Optics, by the Rev. H. Lloyd, M.A., Professor of Natural Philosophy, Dublin.

1835.

On the state of our knowledge respecting the application of Mathematical and Dynamical principles to Magnetism, Electricity, Heat, &c., by the Rev. Wm. Whewell, M.A., F.R.S.

On Hansteen's researches in Magnetism, by Captain Sabine, F.R.S.

On the state of Mathematical and Physical Science in Belgium, by M. Quetelet, Director of the Observatory, Brussels.

1836.

On the present state of our knowledge with respect to Mineral and Thermal Waters, by Charles Daubeny, M.D., F.R.S., M.R.I.A., &c., Professor of Chemistry and of Botany, Oxford.

On North American Zoology, by John Richardson, M.D., F.R.S., &c.

Supplementary Report on the Mathematical Theory of Fluids, by the Rev. J. Challis, Plumian Professor of Astronomy in the University of Cambridge.

1837.

On the variations of the Magnetic Intensity observed at different points of the Earth's Surface, by Major Edward Sabine, R.A., F.R.S.

On the various modes of Printing for the use of the Blind, by the Rev. William Taylor, F.R.S.

On the present state of our knowledge in regard to Dimorphous Bodies, by Professor Johnston, F.R.S.

On the Statistics of the Four Collectorates of Dukhun, under the British Government, by Col. Sykes, F.R.S.

1838.

Appendix to Report on the variations of Magnetic Intensity, by Major Edward Sabine, R.A., F.R.S.

1839.

Report on the present state of our knowledge of Refractive Indices for the Standard Rays of the Solar Spectrum in different media, by the Rev. Baden Powell, M.A., F.R.S., F.G.S., F.R.Ast.S., Savilian Professor of Geometry, Oxford.

Report on the distribution of Pulmoniferous Mollusca in the British Isles, by Edward Forbes, M.W.S., For. Sec. B.S.

1840.

Report on the recent progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science, by the Rev. Baden Powell, M.A., F.R.S., F.R.Ast.S., F.G.S., Savilian Professor of Geometry in the University of Oxford.

Supplementary Report on Meteorology, by James D. Forbes, Esq., F.R.S., Sec. R.S. Ed., Professor of Natural Philosophy in the University of Edinburgh.

The following Reports of Researches undertaken at the request of the Association have been published, viz.

1835.

On the comparative measurement of the Aberdeen Standard Scale, by Francis Baily, Treasurer R.S., &c.

On Impact upon Beams, by Eaton Hodgkinson.

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Ireland, by the Rev. H. Lloyd, Capt. Sabine, and Capt. J. C. Ross.

On the Phænomena usually referred to the Radiation of Heat, by H. Hudson, M.D.

Experiments on Rain at different Elevations, by Wm. Gray, jun., and Professor Phillips.

Hourly observations of the Thermometer at Plymouth, by W. S. Harris.

On the Infra-orbital Cavities in Deers and Antelopes, by A. Jacob, M.D.

On the Effects of Acrid Poisons, by T. Hodgkin, M.D.

On the Motions and Sounds of the Heart, by the Dublin Sub-Committee.

On the Registration of Deaths, by the Edinburgh Sub-Committee.

1836.

Observations on the Direction and Intensity of the Terres-

trial Magnetic Force in Scotland, by Major Edward Sabine, R.A., F.R.S., &c.

Comparative view of the more remarkable Plants which characterize the Neighbourhood of Dublin, the Neighbourhood of Edinburgh, and the South-west of Scotland, &c.; drawn up for the British Association by J. T. Mackay, M.R.I.A., A.L.S., &c., assisted by Robert Graham, Esq., M.D., Professor of Botany in the University of Edinburgh.

Report of the London Sub-Committee of the Medical Section of the British Association on the Motions and Sounds of the Heart.

Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart.

Report of the Dublin Committee on the Pathology of the Brain and Nervous System.

Account of the Recent Discussions of Observations of the Tides which have been obtained by means of the grant of money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association, by J. W. Lubbock, Esq.

Observations for determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.

Provisional Report on the Communication between the Arteries and Absorbents, on the part of the London Committee, by Dr. Hodgkin.

Report of Experiments on Subterranean Temperature, under the direction of a Committee, consisting of Professor Forbes, Mr. W. S. Harris, Professor Powell, Lieut.-Colonel Sykes, and Professor Phillips (Reporter).

Inquiry into the validity of a method recently proposed by George B. Jerrard, Esq., for Transforming and Resolving Equations of Elevated Degrees; undertaken, at the request of the Association, by Professor Sir W. R. Hamilton.

1837.

Account of the Discussions of Observations of the Tides which have been obtained by means of the grant of money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association, by J. W. Lubbock, Esq., F.R.S.

On the difference between the Composition of Cast Iron produced by the Cold and the Hot Blast, by Thomas Thomson, M.D., F.R.SS. L. & E., &c., Professor of Chemistry, Glasgow.

On the Determination of the Constant of Nutation by the

Greenwich Observations, made as commanded by the British Association, by the Rev. T. R. Robinson, D.D.

On some Experiments on the Electricity of Metallic Veins, and the Temperature of Mines, by Robert Were Fox.

Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them.

Report from the Committee for inquiring into the Analysis of the Glands, &c. of the Human Body, by G. O. Rees, M.D., F.G.S.

Second Report of the London Sub-Committee of the British Association Medical Section, on the Motions and Sounds of the Heart.

Report from the Committee for making experiments on the Growth of Plants under Glass, and without any free communication with the outward air, on the plan of Mr. N. I. Ward, of London.

Report of the Committee on Waves, appointed by the British Association at Bristol in 1836, and consisting of Sir John Robison, K.H., Secretary of the Royal Society of Edinburgh, and John Scott Russell, Esq., M.A., F.R.S. Edin. (Reporter).

On the relative Strength and other mechanical Properties of Cast Iron obtained by Hot and Cold Blast, by Eaton Hodgkinson, Esq.

On the Strength and other Properties of Iron obtained from the Hot and Cold Blast, by W. Fairbairn, Esq.

1838.

Account of a Level Line, measured from the Bristol Channel to the English Channel, during the Year 1837–38, by Mr. Bunt, under the Direction of a Committee of the British Association. Drawn up by the Rev. W. Whewell, F.R.S., one of the Committee.

A Memoir on the Magnetic Isoclinal and Isodynamic Lines in the British Islands, from Observations by Professors Humphrey Lloyd and John Phillips, Robert Were Fox, Esq., Captain James Clark Ross, R.N., and Major Edward Sabine, R.A., by Major Edward Sabine, R.A., F.R.S.

First Report on the Determination of the Mean Numerical Values of Railway Constants, by Dionysius Lardner, LL.D., F.R.S., &c.

First Report upon Experiments, instituted at the request of the British Association, upon the Action of Sea and River Water, whether clear or foul, and at various temperatures, upon Cast and Wrought Iron, by Robert Mallet, M.R.I.A., Ass. Ins. C.E.

Notice of Experiments in progress, at the desire of the British Association, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances, by Robert Mallet, M.R.I.A.

Experiments on the ultimate Transverse Strength of Cast Iron made at Arigna Works, Co. Leitrim, Ireland, at Messrs. Bramah and Robinson's, 29th May, 1837.

Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

1839.

Report on the application of the sum assigned for Tide Calculations to Mr. Whewell, in a Letter from T. G. Bunt, Esq., Bristol.

Notice of Determination of the Arc of Longitude between the Observatories of Armagh and Dublin, by the Rev. T. R. Robinson, D.D., &c.

Report of some Galvanic Experiments to determine the existence or non-existence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alston Moor, by H. L. Pattinson, Esq.

Report respecting the two series of Hourly Meteorological Observations kept in Scotland at the expense of the British Association, by Sir David Brewster, K.H., LL.D., F.R.SS. L. and E.

Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle.

Report on British Fossil Reptiles, by Richard Owen, Esq., F.R.S., F.G.S., &c.

Third Report on the Progress of the Hourly Meteorological Register at the Plymouth Dock-yard, Devonport, by W. Snow Harris, Esq., F.R.S.

1840.

Report on Professor Whewell's Anemometer, now in operation at Plymouth, by W. Snow Harris, Esq., F.R.S., &c.

Report on the Motions and Sounds of the Heart, by the London Committee of the British Association for 1839–40.

An Account of Researches in Electro-Chemistry, by Professor Schönbein, of Basle.

Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron, and Steel, by Robert Mallet, M.R.I.A., Ass. Ins. C.E.

Report on the Observations recorded during the Years 1837,

1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham. By A. Follett Osler, Esq.

Report respecting the two series of Hourly Meteorological Observations kept at Inverness and Kingussie, at the Expense of the British Association, from Nov. 1st, 1838, to Nov. 1st, 1839. By Sir David Brewster, K.H., F.R.S., &c.

Report on the Fauna of Ireland: Div. *Vertebrata*. Drawn up, at the request of the British Association, by William Thompson, Esq. (Vice-Pres. Nat. Hist. Society of Belfast), one of the Committee appointed for that purpose.

Report of Experiments on the Physiology of the Lungs and Air-tubes. By Charles J. B. Williams, M.D., F.R.S.

Report of the Committee appointed to try Experiments on the Preservation of Animal and Vegetable Substances. By the Rev. J. S. Henslow, F.L.S.

The following Reports and Continuations of Reports have been undertaken to be drawn up at the request of the Association.

On Salts, by Professor Graham, F.R.S.

On the Differential and Integral Calculus, by the Rev. Professor Peacock, M.A., F.R.S., &c.

On the Geology of North America, by H. D. Rogers, F.G.S., Professor of Geology, Philadelphia.

On Vision, by Professor C. Wheatstone, F.R.S.

On the application of a General Principle in Dynamics to the Theory of the Moon, by Professor Sir W. Hamilton.

On Isomeric Bodies, by Professor Liebig.

On Organic Chemistry, by Professor Liebig.

On Inorganic Chemistry, by Professor Johnston, F.R.S.

On Fossil Reptiles (continuation), by Professor Owen, F.R.S.

On the Salmonidæ of Scotland, by Sir W. Jardine.

On the Caprimulgidæ, by N. Gould, F.L.S.

On the state of Meteorology in the United States of North America, by A. Bache.

On the state of Chemistry as bearing on Geology, by Professor Johnston.

On Molluscous Animals and their Shells, by J. E. Gray, F.R.S.

On Ornithology, by P. J. Selby, F.R.S.E.

On the Specific Gravity of Steam, by a Committee, of which Mr. B. Donkin is Secretary.

On the Temperature of the deep Mines of Cornwall, from his own observations, by W. J. Henwood, F.G.S.

On the recent progress and present condition of Electro-Chemistry and Electro-Magnetism, by Professor de la Rive, of Geneva.

Recommendations for Additional Reports and Researches in Science adopted by the General Committee at the Glasgow Meeting.

ADDITIONAL REPORTS ON THE STATE OF SCIENCE REQUESTED.

Resolved—

That Professor Airy be requested to furnish a second Report on the progress of Astronomy during the present century. The date of the former Report, presented by Professor Airy, is 1831–32.

That a Committee, consisting of the Astronomer Royal, Professor Lloyd, Major Sabine, and Professor Phillips, be appointed to report on the publication or other disposal of Hourly Meteorological Observations now in possession of the Association.
The Report to be presented at the next meeting of the Association.

That Professor Willis be requested to furnish the Report on the state of our knowledge of the Phænomena of Sound, formerly requested.
The Report to be presented at the next meeting of the Association.

That Dr. Peacock be requested to furnish the Report on the Differential and Integral Calculus, formerly requested.
The Report to be presented at the next meeting of the Association.

That Professor Wheatstone be requested to furnish the Report on Vision, formerly requested.
The Report to be presented at the next meeting of the Association.

That Professor Sir W. Hamilton be requested to furnish the Report on the application of a General Principle in Dynamics to the Theory of the Moon, formerly requested.
The Report to be presented at the next Meeting of the Association.

That Professor Kelland be requested to draw up a Report on

the History and present state of the Theory of the Undulations of Fluid and Elastic Media.

The Report to be presented at the next meeting of the Association.

That Professor Kelland be requested to furnish a Report on the relative state of our experimental and mathematical knowledge on the subject of the Conduction of Heat; to point out the experiments already made which require repetition, and those which are necessary to complete the comparison of Theory and Experiment.

The Report to be presented at the next meeting of the Association.

That Professor Bache be requested to furnish his Report on the Meteorology of the United States for the next meeting of the Association.

That a Committee, consisting of Mr. Lubbock, Sir J. W. Herschel, Dr. Robinson, Professor Forbes, Professor Whewell, Professor Miller, Sir David Brewster, and Major Sabine, be requested to report to the Association how far the Desiderata in our knowledge of the condition of the upper strata of the Atmosphere may be supplied by means of ascents in balloons or otherwise; to ascertain the probable expense of such experiments, and draw up directions for observers in such circumstances.

The Report to be presented at the next meeting of the Association.

That Professor Johnston be requested to furnish the Report on Inorganic Chemistry, formerly requested.

That Professor de la Rive, of Geneva, be requested to furnish the Report on the recent progress and present condition of Electro-Chemistry and Electro-Magnetism, formerly requested.

The Report to be presented at the next meeting of the Association.

That Professor Johnston be requested to continue his researches upon Chemical Geology, and to direct his attention particularly to the effects of igneous rocks.

That Dr. Daubeny be requested to prepare a Report on the connexion of Chemistry and Agriculture, formerly requested.

That Sir John Graham Dalyell be requested to prepare a Report on the habits of the Radiate Animals.

That the following be a Committee to inquire into and report on the experiments made by Mr. C. W. Williams, of Liverpool, on the Combustion of Coal and other Fuels, with the view of obtaining from them the greatest calorific effect, and avoiding the generation of smoke, viz. Mr. Vignoles, Mr. Fairbairn, Mr. Grantham, and Mr. Spence.

That Mr. Hodgkinson be requested to complete his experiments on the resistance of the Atmosphere to Moving Bodies, and to report the result to the next meeting of the British Association.

That the following be a Committee to make experiments for ascertaining the comparative efficiency of the Turbine and Common Water Wheels, and to report at the next meeting :—Mr. Smith, of Deanston, Professor Gordon, Mr. W. Fairbairn.

Recommendations of Researches in Science involving Grants of Money for Scientific Purposes, adopted by the General Committee at the Glasgow Meeting.

Resolved—

That Sir D. Brewster and Professor Forbes be requested to revise and continue the Hourly Observations at Inverness and Kingussie, and that a sum not exceeding 85*l.* be placed at their disposal for the purpose.

That a Committee, consisting of Professor Whewell, be requested to superintend calculations on the Tides at Leith by Mr. D. Ross, and that the sum of 50*l.* be placed at the disposal of Professor Whewell for the purpose.
The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Professor Whewell, be requested to superintend calculations on Tides at Bristol by Mr. Bunt, and that the sum of 50*l.* be placed at the disposal of Professor Whewell for the purpose.
The Report to be presented at the next meeting of the Association.

That Major Sabine be requested to provide a good mountain

barometer and a thermometer for the assistance of Mr. M'Cord in his Meteorological Observations, the sum of 20*l.* to be placed at the disposal of Major Sabine for the purpose.

The Report to be presented at the next meeting of the Association.

That the grant of 100*l.* for the reduction of Meteorological Observations, under the superintendence of Sir J. Herschel, be continued.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed for the revision of the Nomenclature of Stars, consisting of Sir John Herschel, Mr. Whewell, and Mr. Baily, be re-appointed, and that the sum of 50*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed for the reduction of the Stars in the Histoire Céleste, consisting of Mr. Baily, the Astronomer Royal, and Dr. Robinson, be re-appointed, and that the sum of 150*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed to extend the Royal Astronomical Society's Catalogue, consisting of Mr. Baily, the Astronomer Royal, and Dr. Robinson, be re-appointed on the condition originally stipulated, that the Catalogue be called the British Association Catalogue, and that 150*l.* be placed at the disposal of the Committee for that purpose.

The Report to be presented at the next meeting of the Association.

That the sum of 40*l.* be granted to Mr. Osler for the purpose of completing the Anemometer in the course of erection at Edinburgh, and also for Tabulating the Observations from the above instruments, in conjunction with those in Birmingham and Plymouth.

The Report to be presented at the next meeting of the Association.

That a sum of 60*l.* be placed at the disposal of Sir D. Brewster, Mr. Osler, and Professor Forbes, for erecting an Ane-

mometer on Mr. Osler's construction at Inverness, to connect these Observations with others already established there.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Major Sabine and Sir J. Herschel, be requested to provide two Actinometers, for Observations on the intensity of Solar Radiation, to be made by Professor Agassiz, at considerable heights in the Alps, and that the sum of 10*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That the sum of 75*l.* be placed at the disposal of Sir D. Brewster, for the purpose of an Inquiry into the action of Gaseous and other Media upon the Solar Spectrum.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed to superintend the reduction of Lacaille's Stars, consisting of Sir J. Herschel, the Astronomer Royal, and Mr. Henderson, be re-appointed; and that the sum of 184*l.* 5*s.* (the balance of former grant) be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That a sum not exceeding 20*l.* be placed at the disposal of Mr. Snow Harris, for repairing and observing Whewell's and Osler's Anemometers.

That a sum of 35*l.* be placed at the disposal of Mr. Snow Harris, for defraying the expenses of the Hourly Register of the Barometer and Thermometer at Plymouth.

That the sum of 20*l.* be placed at the disposal of Professor Forbes, for Tabulating Experiments on Subterranean Temperature.

That a Committee, consisting of Sir J. Herschel, Professor Whewell, Dr. Peacock, Professor Lloyd, and Major Sabine, be appointed for conducting the co-operation of this Association in the system of simultaneous Magnetical and Meteorological Observations, and that a sum of 50*l.* be placed at their disposal.

That a Committee, consisting of Major Sabine, Dr. R. Brown,

Dr. Robinson, Sir J. Herschel, Professor Wheatstone, Sir D. Brewster, and Mr. Owen, Professors Thomas Graham and Miller, Sir W. Jardine, and Professor Robert Graham, be appointed to superintend the Translation and Publication of Foreign Scientific Memoirs; and that the sum of 100*l*. be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That Mr. Mallet be requested to continue his experiments on the Action of Salt and Fresh Water on Iron, &c., and that 50*l*. be placed at his disposal for that purpose.

That a Committee, consisting of Dr. Prout, Dr. J. Thomson, Professor Owen, Professor Graham, and Dr. R. D. Thomson, be requested to undertake a series of Researches on the Chemistry and Physiology of Digestion, and the sum of 200*l*. to be placed at the disposal of the above Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Mr. Bryce, Mr. De la Beche, and Major Portlock, be requested to continue their Researches on the Mud of Rivers, and that the sum of 20*l*. be placed at the disposal of the Committee for that purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of the President of the Royal Society, the President of the Geological Society, R. I. Murchison, Esq., John Taylor, Esq., H. T. De la Beche, Esq., and C. Vignoles, Esq. (with power to add to their number), be requested to take measures for procuring coloured drawings of Railway Sections before they are covered up; 200*l*. to be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of the Marquis of Northampton, R. I. Murchison, Esq., and the Rev. W. Buckland, be requested to enable M. Agassiz to collect materials for a Report on the Fossil Fishes of Scotland, and particularly those of the Old Red Sandstone; 100*l*. to be placed at their disposal for that purpose.

The Report to be presented at the next meeting of the Association.

That Captain Portlock be requested to institute a set of Experiments on the Temperature of Mines in Ireland, and that the sum of 10*l.* be placed at the disposal of Captain Portlock for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Lord Greenock, Mr. Milne, Professor Forbes, Mr. Paterson, Captain Portlock, and Mr. Bryce, be requested to Register the shocks of Earthquakes in Scotland and Ireland, and that the sum of 20*l.* be placed at the disposal of the Committee for that purpose.

The Report to be presented at the next meeting of the Association.

That Professor Johnston and Mr. Jeffreys be a Committee to repeat Mr. Jeffreys's experiments on the Solution of Silica in water of a high temperature, and that the sum of 25*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That Professor Henslow be requested to continue his Researches on the Preservation of Animal and Vegetable Substances, and that the sum of 6*l.*, being the unexpended portion of the former grant, be placed at the disposal of the Committee.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed for the purpose of preparing Maps for the illustration of the Geographical Distribution of Animals and Plants, have the sum of 25*l.* placed at their disposal for the completion of their arrangements.

That the Committee already appointed for the purpose of investigating, by means of the dredge, the Marine Zoology of Britain, be requested to continue their researches, and that the sum of 50*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Sir William Jardine, Mr. Selby, Mr. Yarrell, and Dr. Lankester, be requested to superintend the application of the sum of 50*l.* towards the augmentation of our knowledge of the *Anoplura Britanniæ*.

That a Committee, consisting of Dr. Lankester, Dr. Arnott,

Dr. Greville, and Dr. Fleming, be requested to draw up a Report on the Plants and Animals existing in natural Thermal Springs and Mineral Waters, and in solutions artificially prepared, and that the sum of 6*l.* be placed at the disposal of the above-mentioned Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Mr. Hugh Strickland, Mr. Babington, and Professor Lindley, be requested to institute a series of experiments with a view to determine the longest period during which the Seeds of Plants can retain their vegetative powers, the species or families of Plants in which these powers are of the longest duration, and the circumstances most favourable for their preservation, and that the sum of 10*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented to the next meeting of the Association.

That the Committee already appointed for preparing a series of questions on the Human Race, be requested to complete and distribute the questions, and that the sum of 15*l.* be placed at the disposal of the Committee for the purpose of printing and distributing the queries.

The Report of the Committee to be presented at the next meeting of the Association.

That the Committee already appointed for conducting Experiments on Acrid Poisons be requested to continue their labours, and that the sum of 25*l.* be placed at the disposal of Dr. Roupell for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed for Improvements in Acoustic Instruments be requested to continue their labours, and that the sum of 25*l.* be placed at the disposal of Dr. Yelloly for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed for the investigation of the Communication between Veins and Absorbents be requested to continue their labours, and that the sum of 25*l.* be placed at the disposal of Dr. Roget for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Sir Charles Lemon, Mr. Porter, Mr. Hallam, Colonel Sykes, and Mr. Heywood, be requested to encourage Inquiries into the actual state of Education in Great Britain, considered merely as to numerical analysis, and that the sum of 100*l.* be placed at the disposal of the above-named Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Colonel Sykes, Lord Sandon, Mr. Porter, Mr. Heywood, Dr. Alison, Dr. Cowan, Mr. Chadwick, and Mr. Watt, be requested to inquire into Vital Statistics, and that the sum of 100*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Professor Johnston, Mr. Wharton, Mr. Wilson, Mr. William Murray, Mr. Chas. Baird, Mr. Thomas Edington, jun., Mr. De la Beche, and Mr. D. Milne, be requested to inquire into the Mining Statistics of the British Coal Fields, and that the sum of 25*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Mr. John Enys, Mr. John Taylor, Mr. Fairbairn, Mr. Hodgkinson, Mr. Simpson, and Mr. Scott Russell, be requested to obtain a set of Experiments on the Temperature of *maximum effect* in the Condensers of Steam Engines, and that the sum of 25*l.* be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Sir John Robison and Sir Thomas Brisbane, be requested to procure, and to hold at the disposal of the Association, a set of Roberts's (of Paris) Measurers of short intervals of Time, to be employed, in the first instance, in completing the Experiments on Waves and on the Forms of Vessels; and that the sum of 30*l.* be placed at their disposal for the purpose.

The instruments to be presented at the next meeting of the Association.

That a Committee, consisting of Professor Moseley, Mr. Enys, and Mr. Hodgkinson, be requested to procure the dyna-

mometric apparatus of Mr. Poncelet, and to obtain a series of Experiments on the duty of Steam Engines by means of that apparatus; the sum of 100*l.* to be placed at their disposal for that purpose.

The apparatus to be presented at the next meeting of the Association.

That the Committee already appointed on the Forms of Vessels, be requested to complete their experiments; the sum of 100*l.* to be placed at their disposal for that purpose.

The Report to be presented at the next meeting of the Association.

Synopsis of Sums appropriated to Scientific Objects by the General Committee at the Glasgow Meeting.

SECTION A.

	£	*s.*	*d.*
Hourly Meteorological Observations at Kingussie and Inverness	85	0	0
Tide Discussions: Leith	50	0	0
Tide Discussions: Bristol	50	0	0
Mountain Barometer and Thermometer	20	0	0
Reduction of Meteorological Observations	100	0	0
Nomenclature of Stars	50	0	0
Stars in *Histoire Céleste*	150	0	0
British Association Catalogue of Stars	150	0	0
Reduction of Anemometrical Observations	40	0	0
Erection of Anemometer at Inverness	60	0	0
Two Actinometers	10	0	0
Action of Gases on Light	75	0	0
Lacaille's Stars	284	5	0
Meteorological Observations at Plymouth	35	0	0
Anemometer at Plymouth	20	0	0
Tabulation of Experiments on Subterranean Temperature	20	0	0
Magnetic Co-operation	50	0	0
	£1149	5	0

SECTION B.

Scientific Memoirs	100	0	0
Action of Water on Iron	50	0	0
Chemistry and Physiology of Digestion	200	0	0
	£350	0	0

Section C.

Mud in Rivers	£20	0	0
Railway Sections	200	0	0
Fishes of Old Red Sandstone	100	0	0
Subterranean Temperature in Ireland	10	0	0
Earthquake Registration	20	0	0
Solution of Silica in Water at High Temperatures	25	0	0
	£375	0	0

Section D.

Preservation of Animal and Vegetable Substances	6	0	0
Skeleton Maps	25	0	0
Marine Zoology	50	0	0
Anoplura Britanniæ	50	0	0
Plants and Animals in Mineral Waters	6	0	0
Vegetative power of Seeds	10	0	0
Races of Men	15	0	0
	£162	0	0

Section E.

Acrid Poisons	25	0	0
Acoustic Instruments	25	0	0
Veins and Absorbents	25	0	0
	£75	0	0

Section F.

Statistics of Education	100	0	0
Vital Statistics	100	0	0
Mining Statistics	25	0	0
	£225	0	0

Section G.

Temperature of *maximum condensation* of Steam	25	0	0
Roberts' Chronometers	30	0	0
Dynamometric Instruments	100	0	0
Forms of Vessels	100	0	0
	£255	0	0

Total of Money Grants £2591 5 0

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money for scientific purposes have been entrusted, are required to present to each following meeting of the Association a Report of the progress which has been made; with a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Association expire at the ensuing meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

In each Committee, the Member first named is the person entitled to call on the Treasurer, John Taylor, Esq., 2, Duke Street, Adelphi, London, for such portion of the sum granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the Members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named shall be deemed to include the specified balance which may remain unpaid on the former grant for the same object.

On Thursday evening, September 17th, the President, the Most Noble the Marquis of Breadalbane, took the Chair in the Theatre. Mr. Murchison read the Address of the General Secretaries (see next page).

On Wednesday, at 3 P.M., the CONCLUDING GENERAL MEETING of the Association took place in the Theatre, when an account of the PROCEEDINGS OF THE GENERAL COMMITTEE was read by Major Sabine.

ADDRESS

BY

RODERICK IMPEY MURCHISON, F.R.S., F.G.S.

AND

MAJOR EDWARD SABINE, V.P.R.S.

IN entering upon the duty assigned to us, we heartily congratulate our associates on this our second assembly in Scotland. As on our first visit we were sustained by the intellectual force of the metropolis of this kingdom, so now, by visiting the chief mart of Scottish commerce, and an ancient seat of learning, we hope to double the numbers of our northern auxiliaries.

Supported by a fresh accession of the property and intelligence of this land, we are now led on by a noble Marquis, who, disdaining not the fields we try to win, may be cited as the first Highland chieftain who, proclaiming that knowledge is power, is proud to place himself at the head of the clans of science.

If such be our chief, what is our chosen ground?—raised through the industry and genius of her sons, to a pinnacle of commercial grandeur, well can this city estimate her obligations to science! Happily as she is placed, and surrounded as she is by earth's fairest gifts, she feels how much her progress depends upon an acquaintance with the true structure of the rich deposits which form her subsoil; and great as they are, she clearly sees that her manufactures may at a moment take a new flight by new mechanical discoveries. For she it is, you all know, who nurtured the man whose genius has changed the tide of human interests, by calling into active energy a power which (as wielded by him), in abridging time and space, has doubled the value of human life, and has established for his memory a lasting claim on the gratitude of the civilized world. The names of Watt and Glasgow are united in imperishable records!

In such a city, then, surrounded by such recollections, encouraged

by an illustrious and time-honoured university, and fostered by the ancient leaders of the people, may we not augur that this Meeting of the British Association shall rival the most useful of our previous assemblies, and exhibit undoubted proofs of the increasing prosperity of the British Association?

Not attempting an analysis of the general advance of science in the year that has passed since our meeting at Birmingham, we shall restrict ourselves, on the present occasion, to a brief review of what the British Association has directly effected in that interval of time, as recorded in the last published volume of our Transactions. From this straight path of our duty we shall only deviate in offering a few general remarks on subjects intimately connected with the well-being and dignity of our Institution.

One of the most important—perhaps the most important service to science—which it is the peculiar duty of the Association to confer, is that which arises from its relation to the Government,—the right which it claims to make known the wants of science, and to demand for them that aid which it is beyond the power of any scientific body to bestow. In the fulfilment of this important and responsible duty, the Association has continued to act upon the principle already laid down in the Address of the General Secretaries at the meeting at Newcastle in 1838, namely, to seek the aid of Government in no case of doubtful or minor importance; and to seek it only when the resources of individuals, or of individual bodies, shall have proved unequal to the demand. The caution which it has observed in this respect has been eminently displayed in the part which it has taken with reference to the Antarctic expedition, and to the fixed magnetical observatories. It abstained from recommending the former to the Government until it had called for, and obtained from Major Sabine, by whom the importance of such an expedition was first urged, a report in which that importance was placed beyond all doubt; and it withheld from urging the latter, although its necessity was fully felt by some of its own members, until the letter of Baron Humboldt to the Duke of Sussex gave authority and force to its recommendation.

The delay which has in consequence occurred, has been productive of signal benefit to each branch of this great twofold undertaking. Since the time alluded to, our views of the objects of investigation in terrestrial magnetism have been greatly enlarged, at the same time that they have become more distinct. Major Sabine's memoir on the Intensity of Terrestrial Magnetism has served to point out the most interesting portions of the surface of the globe, as respects the distri-

bution of the magnetic force, and has indicated, in the clearest manner, what still remained for observation to perform; and the beautiful theory of M. Gauss, which has been partly built upon the data afforded by the same memoir,—while it has assigned the most probable configuration of the magnetic lines of declination, inclination, and intensity,—has done the same service with respect to all the three elements.

In another point of view, also, delay has proved of great value to both branches of the undertaking, but more especially to the fixed observatories. Our means of instrumental research have, since the time of their first projection, received great improvements, as well in their adequacy to the objects of inquiry, as in their precision; and finally, the two great lines of inquiry—the research of the distribution of Terrestrial Magnetism on the earth's surface,—and the investigation of its variations, secular, periodic, and irregular,—have been permitted to proceed *pari passu.*

Last of all, the prudent caution, and vigilant care, which the two great scientific bodies, the Royal Society and the British Association, have exhibited, both in the origin and progress of the undertaking, have naturally inspired the Government with confidence; and while on the one hand science has not hesitated to demand of the country all that was requisite to give completeness to a great design, so on the other, the Government of the country has not hesitated to yield, with a liberal and unsparing hand, every request the importance of which was so well guaranteed.

But while we thus enumerate the benefits which have resulted to magnetical science from the delay, it must be also acknowledged that something has been lost also, not to science, but to British glory. Although terrestrial magnetism stood forward as the prominent object of the Antarctic expedition, yet it was also destined to advance our knowledge of the "*physique du globe,*" in all its branches, and especially in that of geography. Had the project of an Antarctic expedition been acceded to when it was first proposed, viz. at the meeting of the British Association, in Dublin, in 1835, there can be no reasonable doubt, that a discovery of coast, which by its extent may almost be designated as that of a Southern Continent, situated in the very region to which its efforts were to have been chiefly directed, must have fallen to its lot; and the flag of England been once more the first to wave over an unknown land. But while, as Britons, we mourn over the loss of a prize which it well became Britain and British seamen to have made their own, it is our part too as Britons, as well as men of science, to hail the great discovery—one of the very few great geographical dis-

coveries which remained unmade;—and to congratulate those by whom it has been achieved, those whom we are proud to acknowledge as fellow-labourers, and who have proved themselves in this instance our successful rivals in an honourable and generous emulation.

The caution which has characterized the British Association in the origination of this great undertaking, has been followed up by the Royal Society in the manner in which it has planned the details, and in the vigilant care with which it has watched over the execution. Of the success which has attended this portion of the work, the strongest proof has been already given in the unhesitating adoption of the same scheme of observation by many of the continental observers, and in the wide extension which it has already received in other quarters of the globe. All that yet remains is to provide for the speedy publication of the results. The enormous mass of observations which will be gathered in, in the course of three years, by the observatories established under British auspices, and by the Antarctic expedition, will render this part of the task one of great expense and labour. To meet the former, we must again look to the Government, and to the East India Company, who will certainly not fail to present the result of their munificence to the world in an accessible form. The latter can only be overcome by a well-organized system. The planning of this system, will, of course, be one of the first duties of the Royal Society; and it is important that it should be so arranged, that while every facility in the way of reduction may be given to those who shall hereafter engage in the theoretical discussion of the observations, care is taken at the same time that the data are presented entire, without mutilation or abridgement. The Council of the Royal Society, will, doubtless, be greatly assisted in this duty by the eminent individual who has had in every way so large a share in the formation of these widely scattered magnetic establishments, and whose own observatory, founded by the munificence of the Dublin University, has nearly completed a twelve months' magnetic observations on that enlarged and complete system of which it set the first example.

In referring, as we have done, to those most valuable services which the Royal Society have rendered, and are continuing to render, in directing and superintending the details of this great undertaking, in both its branches, it is right that, on the part of the British Association, we should express the cordial satisfaction and delight with which we have witnessed their exertions, united with our own in this common cause; nor should we omit to recognize how much this desirable concurrence has been promoted by the influence of the noble President of the Royal Society, the Marquis of Northampton, whom, as on so many

former occasions, we have the pleasure of seeing amongst us,—one of our warmest supporters and most active members.

In the volume of our Transactions now under notice, is contained the memorial presented to Lord Melbourne by the Committee of the British Association, appointed to represent to Her Majesty's Government the recommendations of the Association on the subject of Terrestrial Magnetism. This memorial is one of many services which have been rendered to our cause by Sir John Herschel, whose name, whose influence, and whose exertions, since our meeting two years since at Newcastle, have largely contributed to place the subject where it now stands. The devoted labour of other of our members has long been given to an object which they have had deeply at heart, viz. the advancement of the science of terrestrial magnetism; but the sacrifice which Sir John Herschel has made of time, diverted from the great work, in which his ardent love of astronomy, his own personal fame, and his father's memory are all deeply concerned, the more urgently demands from our justice a grateful mention, because the science of magnetism had no claim on him, beyond the interest felt in every branch of science, by one to whom no part of its wide field is strange, and the regard which a national undertaking such as this deserved, from the person who occupies his distinguished station amongst the leaders of British science.

The advancement of human knowledge, which may be reckoned upon as the certain consequence of the Antarctic expedition (should Providence crown it with success), and of the arrangements connected with it, is of so extensive a nature, and of such incalculable importance, that no juster title to real and lasting glory than it may be expected to confer, has been earned by any country at any period of time; nothing has ever been attempted by England more worthy of the place which she occupies in the scale of nations. When much which now appears of magnitude in the eyes of politicians has passed into insignificance, the fruits of this undertaking will distinguish the age which gave it birth, and, engraved on the durable records of science, will for ever reflect honour on the scientific bodies which planned and promoted it, and on the Government which, with so much liberality, has carried it into effect.

Were the value of this Association, Gentlemen, to be measured only by the part which it has taken in suggesting and urging this one object, there might here be enough to satisfy the doubts of those who question its utility. To overlook such acts as these, and the power of public usefulness which they indicate, to scrutinize with microscopic

view the minute defects incidental to every numerous assemblage of men, to watch with critical fastidiousness the taste of every word which might be uttered by individuals amongst us, instead of casting a master's eye over the work which has been done, and is doing, at our meetings, is no mark of superior discernment and comprehensive wisdom, but is evidence rather of a confinement to narrow views, and an indulgence of vain and ignoble passions.

But to proceed with our useful efforts,—one of the principal objects of our Annual Volumes, is the publication in the most authentic form of the results of special researches, undertaken by the request, and prosecuted in many instances at the cost, of the Association. It is a trite remark, that if a man of talent has but fair play, he will soon secure to himself his due place in public estimation. We fully admit the truth of this in many instances, and above all where the points of research are connected with commerce and the useful arts; but many also are the subtile threads of knowledge, which, destined at some future day to be woven into the great web in which all the sciences are knit together, are yet not appreciable to the vulgar eye, and if simply submitted to public judgment, would too often meet with silent neglect. Numberless, we say, are the subjects (and if your Association exceeds a centenary, still more numerous will they be) with which the retired and skilful man may wish to grapple, and still be deterred by his want of opportunity or of means. Then is it that, adopting the well-balanced recommendations of the men in whose capacity and rectitude you confide, you step forward with your aids, and bring about these recondite researches, the result of which, in the volume under our notice, we now proceed to consider.

The first of these inquiries to which we advert, you called for at the hands of Professor Owen, upon "British Fossil Reptiles," one of the branches of Natural History, on a correct knowledge of which the development of geology is intimately dependent.

The merits of the author selected for this inquiry are now widely recognized, and he has, with justice, been approved as the worthy successor of John Hunter, that illustrious Scotchman who laid the foundation of comparative anatomy in the British isles. That this science is now taking a fresh spring, would, we are persuaded, be the opinion of Cuvier himself, could that eminent man view the progress which our young countryman is making towards the completion of the temple of which the French naturalist was the great architect. It is therefore a pleasing reflection, that when we solicited Professor Owen to work out this subject, we did not follow in the wake of Europe's praise, but

led the way (as this Association ought always to do), in drawing forth the man of genius and of worth; and the value of our choice has been since stamped by the approval of the French Institute.

If Englishmen* first perceived something of the natural affinities of Palæosaurians, it was reserved for Cuvier to complete all such preliminary labour. The publication of his splendid chapters on the osteology of the crocodile and other reptiles, drew new attention and more intelligent scrutiny to these remains; and it ought to be a subject of honest pride to us to reflect, that the most interesting fruits of the researches of that great anatomist were early gathered by the English palæontologists, Clift and Hume. One of our leaders†, whose report on geology ornaments the volumes of this Association, formed the genus *Plesiosaurus*, on an enlarged view of the relation subsisting between the ancient and modern forms of reptile life; while shortly after Buckland established the genus *Megalosaurus*, and Mantell, *Iguanodon* and *Hylæosaurus*, worthy rivals of the *Geo-Sauri* and *Moso-Sauri* of Cuvier. The other Englishmen who have best toiled in this field, are De la Beche, Hawkins, and Sir Philip Egerton.

Yet although this report is on *British* reptiles, we are fully alive to the great progress which this department has made, and is making, on the Continent, through the labours of Count Münster, Jäger, and Hermann Von Meyer. The last-mentioned naturalist has been for some time preparing a series of exquisite drawings of very many forms unknown to us in England, most of which have been detected in the "Muschelkalk," a formation not hitherto discovered in the British isles. Yet despite of all that had been accomplished in our own country or elsewhere, Professor Owen has thrown a new light of classification on this subject, founded on many newly discovered peculiarities of osseous structure, and has vastly augmented our acquaintance with new forms, by describing sixteen species of *Plesiosauri*, three of which only had been recognisably described by other writers; and ten species of Ichthyosauri, five of which are new to science. Such results were not to be obtained without much labour; and previous to drawing up his report, Professor Owen had visited the principal depositories of *Enaliosauri* described by foreign writers, as well as most of the public and private collections of Britain. This, the first part of Mr. Owen's report, concludes with a general review of the geological relations and extent of the strata through which he has traced the remains of British Enaliosauri. The materials which he has collected for the second and concluding portion of his report on the terrestrial and crocodilean

* Stukeley. † Conybeare.

Sauria, the Chelonia, Ophidian, and Batrachian reptiles, are equally numerous, and the results of these researches will be laid before the Association at our next meeting. Deeply impressed as we are with the value of this report, we cannot conclude a notice of it, without again alluding to its origin, in the words of Professor Owen himself. "I could not," says he, "have ventured to have proposed to myself the British Fossil Reptilia as a subject of continuous and systematic research, without the aid and encouragement which the British Association has liberally granted to me for that purpose."

Mr. Edward Forbes, whose labours in detecting the difference of species and varieties among the existing marine testacea of our shores, have been most praiseworthy, has on this occasion given us a valuable report on the pulmoniferous mollusca of the British isles. The variations in the distribution of the species in this class of animals, are shown by him to depend both upon climate and upon soil, the structure of the country (or geological conditions) having quite as much share in such varied distribution, as the greatest diversity of temperature. The Association has also to thank the author for most useful tables, which show the distribution of the pulmoniferous mollusca in our islands, and their relations to those of Europe generally.

One of the most interesting fruits of modern experimental research is the knowledge of the fact, that electrical currents are in continual circulation below the surface of the earth. Whether these currents, so powerful in developing magnetical and chemical phænomena, are confined to mineral veins and particular arrangements of metal and rock, or generally capable of detection by refined apparatus well applied, appeared a question of sufficient importance to deserve at least a trial on the part of the Association. Our present volume records the result of such a trial on the ancient and very regularly stratified rocks of Cumberland, consisting of limestone, sandstone, shale, and coal, so superimposed in many repetitions as to resemble not a little the common arrangement of a voltaic pile. Varied experiments, with a galvanometer of considerable delicacy, failed, however, to detect, in these seemingly favourable circumstances, any electrical current.

The extensive and rapidly increasing applications of iron to public and private structures of all kinds in which durability of material is a first requisite, have made it highly desirable to possess accurate information respecting the nature of the chemical forces which effect the destruction of this hard and apparently intractable metal. The preservation of iron from oxidation and corrosion is indeed an object of paramount importance in civil engineering. The Association was, therefore, anxious to direct inquiry to this subject, and gladly availed itself

of the assistance of Mr. Mallet, a gentleman peculiarly qualified for such investigations, both from his knowledge as a chemist, and from his opportunities of observation as a practical engineer. An extensive series of experiments has accordingly been instituted by him, with the support of the Association, on the action of sea and river water, in different circumstances as to purity and temperature, upon a large number of specimens of both cast and wrought iron of different kinds. These experiments are still in progress, and the effects are observed from time to time. They will afford valuable data for the engineer, and form the principal object of the inquiry; but a period of a few years will be required for its completion. In the mean time, Mr. Mallet has furnished a report on the present state of our knowledge of the subject, drawn from various published sources, and from his own extensive observations. In this report he examines very fully the general conditions of the oxidation of iron, and how this operation is greatly promoted, although modified in its results, by sea water; also in what manner the tendency to corrosion is affected by the composition, the grain, porosity, and other mechanical properties of the different commercial varieties of iron. The influence of minute quantities of other metals, in imparting durability to iron, is also considered. Mr. Mallet devotes much attention to the consequences of the galvanic association of different metals with iron, a subject of recent interest from the applications of zinc and other metals to protect iron, which are at present agitated. He concludes this, his first report, by recommending a series of inquiries, ten in number, which will supply the desiderata immediately required by the engineer and by the chemist.

We have next to notice a report by Professor Powell, on the present state of our knowledge of refractive indices for the standard rays of the solar spectrum in different media. The difficulty which the fact of the dispersion of light has offered to the universal application of the undulatory theory, has been in a great measure removed by the analysis of Cauchy and others, who have considered the distances of the undulatory particles as quantities comparable to the length of a wave; velocities of propagation of the different rays of the spectrum are made to depend upon the length of wave which constitutes a ray of a given colour, and upon certain constants proper to the medium; these constants being obtained from observations on refractive indices for certain definite rays (or dark lines) of the spectrum, the refrangibility of any other definite ray (whose wave-length has been ascertained by examining an interference-spectrum) becomes known, and may be compared with observation as a test of theory; such experiments have been made by Frauenhofer, Rudberg, and Professor Powell, who has

given a tabular view of the various results, without, however, instituting the comparison between theory and observation, which it would be desirable to extend further than has yet been done. It would be important also to elucidate the disturbing effect of temperature, which prevents even existing observations from being rigorously comparable.

The calculations respecting the tides, which have been prosecuted by the aid of the Association ever since its institution, have been continued this year by Mr. Bunt, under the directions of Mr. Whewell. These calculations have now reached such a point, that the mathematician, instead of being, as at the beginning of this period, content with the first rude approximations, is now struggling to obtain the last degree of accuracy.

The country in which we are now assembled, has always been conspicuous for attention to meteorology, a branch of physical science, in which the British Association, with its power of combining the efforts of many observers in distant quarters of the globe, may hope to be especially useful.

In Scotland, Leslie opened a new train of inquiry, by examining the earth's temperature at different depths; and his successor in the University of Edinburgh, is now directing, at the request of the Association, a large and complete course of experiments on that interesting subject. Framed in conformity with the plans adopted for similar objects by Arago and Quetelet, these researches of Professor Forbes contain also the means of determining the power of conducting heat, which different sorts of rock possess; and may thus throw light on some of those peculiarities in the distribution of temperature at greater depths below the surface, which have become known by experience, but are not explained by theory.

In Scotland, Sir David Brewster was the first to obtain an hourly meteorological journal for a series of years, and to draw from that fertile source new and important deductions, which have had a powerful influence on the progress of scientific meteorology. How gratifying to receive, through the same hands, after the lapse of nearly 15 years an additional contribution of the same kind, and from the same country; but embracing new conditions, on a new line of operations, in order to obtain new results! By the observations now in progress at Inverness and at Kingussie, the influence of elevation in modifying the laws, which have been found to govern the hourly distribution of heat near the level of the sea, may be discovered, and thus a great addition be made to the experimental results, for which science has long been grateful to the distinguished philosopher we have named, and which

have been described as "the highest value to meteorology, and as the only channel through which any specific practical information can be obtained in this most interesting department of physics."

This is no ordinary praise. It is the just tribute of one who is worthy to offer it; one, who at the call of the British Association, has conducted at Plymouth a still more extensive series of similar observations, and has added to them hourly comparisons of the temperature and moisture of the air, and an hourly record of barometric oscillations. Mr. Snow Harris has presented in a few pages of our last report, the precious results of (70,000) observations, and thus rendered them immediately available in the foundations of accurate meteorology. The documents thus patiently collected, are, however, not yet exhausted in value; they may be again and again called into the court of science, and made to yield testimony to other, and as yet, unsuspected truths. They must not be lost. Shall we lay them by in manuscript among other unconsulted records of the past labours of men, or by undertaking their publication, do justice to our workmen, and establish a new claim on the imitation of the present, and the gratitude of future days? This question is of serious import. Already, stimulated by success in thermometric registration, we have set to work on a more perplexing problem; we have resolved to bind even the wandering winds in the magic of numbers. While we speak, the beautiful engines of our Whewells and Oslers are tracing at every instant of time, the displacements of the atmosphere at Cambridge, at Plymouth, at Birmingham, in Edinburgh, in Canada, in St. Helena, and at the Cape of Good Hope; and ere long we may hope to view associated in one diagram, the simultaneous movements of the air over Europe, America, Africa, India, and Australia, recorded with instruments which we have chosen, by men whom we have set to work.

Amongst the causes which tend to retard the progress of science, few, perhaps, operate more widely than the impediment to a free and rapid communication of thought and of experiments, occasioned by difference of language. It appeared to the British Association, that this impediment might in some degree be removed, as far as regards our own country, by procuring, and causing to be published, translations of foreign scientific memoirs judiciously selected. Accordingly at each of the meetings at Newcastle and Birmingham a grant was placed at the disposal of a committee appointed to carry this purpose into effect. Aided by several contributions which have been gratuitously presented to them, the committee have been enabled in the two last years, to publish translations of fourteen memoirs on subjects of

prominent interest and importance in the mathematical and physical sciences, bearing the names of some of the most eminent of the continental philosophers.

In concluding this imperfect review of our recent proceedings, we are led to observe, that in two essential respects the British Association differs from all the annual scientific meetings of the Continent; no one of which has *printed Transactions or employed money in aiding special researches.* We also differ from them in the communications which, in the name of the representatives of science assembled from all parts of the United Kingdom, we feel ourselves authorized to make to our Government, on subjects connected with the scientific character of the nation. On our first visit to Scotland, for example, we felt it to be an opprobrium, that this enlightened kingdom should, in one essential feature of civilization, be still behind many of the continental states; and we prepared an address to his late Majesty's Government, urging the necessity for the construction, without delay, of a map of Scotland, founded on the trigonometrical survey. Representations to the same effect have since been made by the Royal Society of Scotland, and by the Highland Society, and the subject has *now* engaged that attention, which will, we trust, soon procure for this country the first sheets of a large and complete map.

Should it then be asked, why are the men of highest station happy to associate and mingle with us in official duties?—why have the heads of the noble houses of Fitzwilliam, Lansdowne*, Northampton, Burlington, Northumberland, and Breadalbane, alternated in presiding over us, with our Bucklands, our Sedgwicks, our Brisbanes, our Lloyds, and our Harcourts?—why indeed, on this very occasion, has Argyll himself, overlooking the claims due to his high position, and his ancient lineage, come forward to act with us, and even to serve in a subordinate office? may we not reply, that it is, we believe, a consequence of the just appreciation on the part of these patriotic and enlightened noblemen, of the beneficial influences which this Association exercises in so many ways on the sources of the nation's power and honour?

If we have hitherto dwelt almost exclusively on the value of our transactions, researches, recommendations, and the good application of our finances, let it not, however, be supposed, that we are not also

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* The Marquis of Lansdowne, who had accepted the office (1836), was prevented from attending by deep domestic affliction, and the Marquis of Northampton cheerfully supplied his place.

alive to the advantages which flow from the social intercourse of these meetings, by bringing together, into friendly communion, from distant parts, those who are struggling on in advancing experimental science. This principle of union (which we are proud to have borrowed from our German brethren) has indeed been hitherto found to work so well amongst our own countrymen, that we cannot but doubly recognize its value when we see assembled so many distinguished persons from foreign countries. In the presence of these eminent men*, we forbear to allude to individual distinctions, conscious that any brief attempt of our own would fall far short of a true estimate of merits, the high order of which is known to every cultivator of science. Well, however, may we rejoice in having drawn such spirits to our Isle; valuable, we trust, may be the comparisons we shall make between the steps which the sciences are making in their countries and in our own.

That advantages, indeed, of no mean order arise from such social intercourse, is a feeling now so prevalent, that foreign national associations for the promotion of natural knowledge, have rapidly increased. Germany, France, and Italy have their annual Assemblies, and our allies of the Northern States hold their sittings beyond the Baltic. In all this there is doubtless much good, but an occasional more extensive intercourse of a similar nature, to be repeated at certain intervals, is greatly to be desired.

It has therefore appeared to us (and we say it after consultation with many of our continental friends, who equally feel the disadvantage), that the formation of a general congress of science might be promoted at this meeting, which, not interfering with any assemblies yet fixed upon, or even contemplated, may be so arranged as to permit the attendance of the officers and active members of each national scientific institution.

Should the British Association take the first step in proposing a measure of this kind by soliciting the illustrious Humboldt to act as President, we are sure that scientific men of all nations would gladly unite in offering this homage to a man whose life and fortune have been spent in their cause, whose voice has been so instrumental in awakening Europe to the inquiry into the laws of terrestrial magnetism, and whose ardent search after nature's truths has triumphed over the Andes and the Altai.

If such be your suggestion, then will a fresh laurel be added to the wreath to this city. She who, through the power bequeathed to her by

* Encke, Link, Jacobi, &c.

her illustrious offspring, conveys with rapid transit her inventions and her produce to the remotest lands, well can she estimate the value of an union of men whose labours can but tend to cement the bonds of general peace. In such a body the British representatives would, we trust, form no inconspicuous band; and with minds strengthened by the infusion of fresh knowledge, they would, on re-assembling for our own national ends, the better sustain the permanent and successful career of the *British Association*.

REPORTS

ON

THE STATE OF SCIENCE.

Report on the recent progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the 1*st volume of the Reports of the British Association for the Advancement of Science. By the Rev.* BADEN POWELL, M.A., F.R.S., F.R.Ast.S., F.G.S., *Savilian Professor of Geometry in the University of Oxford.*

HAVING been one of those whoat the first institution of the British Association were applied to, to prepare reports on the state and progress of the different branches of science, and having in consequence laid before the Association at the Oxford meeting in 1832 such a review of the subject of Radiant Heat, I have felt peculiar satisfaction in being again honoured by a request from the Council to furnish a second report supplementary to the former, embracing the progress of knowledge in that department from the period to which the first report extends, up to the present time.

Such a supplementary account has been rendered peculiarly necessary, from the great number and high importance of the results which have been arrived at by several eminent experimenters in the interval which has elapsed: and though much is still required to be done before we attain complete and satisfactory grounds for an unexceptionable theory of radiant heat, yet the discoveries recently made have at least tended greatly to modify all our previous conceptions, and to enable us to refer large classes of the phænomena to something like a simple and common principle.

In my former Report I divided the subject under various heads, derived from what appeared, in the existing state of our know-

ledge, well-marked distinctions between several kinds of effects ascribed to radiant heat. The more recent discoveries have in a great degree so changed our views of the subject, that these divisions cannot with any advantage or convenience be adhered to. One grand principle of arrangement, however, has been newly supplied in the capital discovery of the polarization of heat; so that all the researches we have to describe will be conveniently classed under two heads, as they relate—first, to radiant heat in its ordinary or unpolarized state; and secondly, to its polarized condition.

Division I.—Unpolarized Heat.

Transmission and Refraction of Heat: Melloni.

Since the period to which my former report extends, various notices have from time to time been given to the British Association relative to the more important discoveries connected with radiant heat. My former report includes a statement of some of the first researches of M. Melloni. At the Cambidge meeting, in 1833, Prof. Forbes gave some account of the further investigations in which M. Melloni was then engaged, including a brief abstract by M. Melloni himself of the chief results he had then obtained*. The full details were subsequently embodied in his several memoirs.

In the earlier part of these researches, M. Melloni had found that the quantity of calorific rays which traverses a screen, is proportional to the temperature of the source: but the difference constantly diminishes as the thickness of the screen is less, until with very thin laminæ it is insensible.

This proves that the resistance to the passage of heat is *not* exerted at the *surface*, but in the interior of the mass.

With the solar rays, he observed that with various thicknesses of sulphate of lime, water and acids, the increase of interception, owing to increased thickness, is *greater* for the *less* refrangible rays of the spectrum.

With terrestrial sources he found that a plate of glass, 2 mm. in thickness, stops, out of 100 rays, from flame 45, from copper at 950° cent. (incandescent) 70, from boiling mercury 92, from boiling water 100.

Comparing the transmissive powers of a great number of substances in a crystallized state, he concluded that the diathermaneity for the rays of a lamp was proportional to their refractive powers; but in uncrystallized bodies no such law could be traced.

* See Third Report, p. 381-2.

It was in the course of these researches that the author made the important discovery of the singular property possessed by Rock Salt, viz. that it is almost entirely permeable to heat even from non-luminous sources. He found its transmissive power six or eight times greater than that of an equal thickness of alum, which had nearly the same transparency and refractive power. He also discovered that (unlike other diathermanous media) it is *equally* diathermanous to *all species* of heat, *i. e.* to heat from sources of all degrees of luminosity or obscurity; or that it transmits in every case an equal proportion of the heat incident.

Thus he found a plate of 7 mm. (·28 inch) in thickness transmits about 92 out of 100 rays, whether from flame, red-hot iron, water at 212°, or at 120° Fahrenheit. A plate 1 inch thick gave a similar constant ratio.

M. Melloni's "Memoir on the Free Transmission of Radiant Heat through Solid and Liquid Bodies," was presented to the Academy of Sciences at Paris, Feb. 4, 1833, and published in the Ann. de Chimie, No. liii. p. 1; a translation of it is given in Taylor's Scientific Memoirs, Part I.

The author commences with a slight sketch of the researches of previous experimenters, but omits to notice any distinctions between the *characters* of the heat from different sources, or the different *kinds* of heat from one and the same source, when luminous, especially as indicated by my experiments published in the Phil. Trans. for 1825.

He then proceeds to some "general considerations on free transmission of caloric through bodies, and the manner of measuring it by means of the thermo-multiplier." This, in fact, constitutes a supplementary and more enlarged portion of his former researches. He goes into extensive details on the precautions necessary to be used in such investigations; especially for guarding against the interference of secondary radiation: as this changes with the change of place of the screen, he thus allows for its effects. He also gives some general observations on the use of the galvanometer, and the correct estimation of the forces acting upon it.

The next subject of inquiry is the effect due to "the polish, thickness, and nature of the screens." The source of heat being a lamp, screens were employed of glass rendered of different degrees of opacity by grinding, &c.; and the effects by transmission through them were found to be in proportion to the transparency, or that the heat follows the same proportion as the light.

The effect of liquids between glass plates was then tried; and more rays were found to be absorbed in proportion to the increase

of thickness. Different numbers of glass screens were also employed in combination; the same conclusion also held good.

The results with a numerous series of screens of various media, solid and liquid, were then tried, and are stated in a series of tables:—

Table I. Various kinds of uncoloured glass.

Table II. Liquids: to give a general sketch, the order of transmission was as follows, beginning with the greatest:—

Carburet of silver.
Chlorides.
Oils.
Acids.
Water.

Table III. Crystallized bodies, transparent and opake; the results follow no relation to transparency: the following is the general order:—

Rock salt.
Various crystals.
Alum.
Sulphate of copper—no effect.

Table IV. Coloured glasses. Red and violet transmitted most—yellow, green and blue, least—heat.

The author concludes, in general (the source being a lamp), that the diathermancy is not proportional to the transparency; and makes some general remarks on these results as related to those of Seebeck on prismatic dispersion.

A supplement to the last paper was presented by the same author to the Academy, April 21, 1834, entitled "New Researches on the immediate Transmission of Radiant Heat through different Solid and Liquid Bodies." It is published in the Ann. de Chimie, lv. 337, and translated in Taylor's Scientific Memoirs, Part I., p. 39.

The author first investigates "the modifications which calorific transmission undergoes in consequence of the radiating source being changed."

He employs four sources of heat. 1. A Locatelli lamp. 2. Incandescent platina. 3. Copper heated by flame to about 730° Fahrenheit. 4. Hot water in a blackened copper vessel. The heat from each of these sources was first compared as transmitted through plates of glass of different thicknesses, from ·07 millims. to 8 millims. The results are given in a table, from which it appears that with copper and hot water the diminution of effect is rapid, with an increase of thickness in the screen; with water it is nothing beyond a thickness of ·5 mm. A second table gives results for about 40 solid media of different kinds, of

the same thickness; most of them were wholly impervious to dark heat; the most remarkable exceptions being fluate of lime and rock salt.

In another table are the results with black glass and black mica; these substances, though diathermanous to the lamp and incandescent platina, are wholly impervious to the rays from hot water, and nearly so to those from heated copper.

The discovery of the entire diathermancy of rock salt has been before referred to, and has furnished the means of prosecuting the author's yet more remarkable researches on the Refraction of Heat.

To this important point M. Melloni devotes a portion of the same memoir. After a sketch of previous attempts to establish this property, he describes his successful experiment by concentrating to the focus of a *rock-salt lens* the rays of *dark heat* from hot copper and hot water. *A similar lens of alum* produced *no* effect; this proves that the effect is not due to the mere heating of the central part of the lens.

He next advances to the refraction of heat by a rock-salt *prism;* describing an apparatus for the purpose. That the effect is not due to secondary radiation, is shown by turning the prism on its axis into a different position, when no effect is produced.

He then discusses the "properties of the calorific rays immediately transmitted by different bodies." Under this head are detailed one of the most remarkable species of effects which the whole range of the subject presents.

The rays of the lamp were thrown upon screens of different substances in such a manner, that either by changing the distance, or by concentration with a mirror, or a lens of rock salt, the effect transmitted from all the screens was of a certain constant amount. This *constant radiation* was then intercepted by a plate of *alum*, and it was found that *very different proportions of heat were transmitted by the alum in the different cases.* This very singular result is established by numerous detailed experiments, of which a tabular statement is given, and the author states it in the following terms: "*the calorific rays issuing from the diaphanous screens are therefore of different qualities, and possess, if we may use the term, the diathermancy peculiar to each of the substances through which they have passed.*"

He next investigates the effects of *different colours* in *glass* on the absorption of heat. He infers in general that the colouring matter diminishes the power of transmission, and examines the question, does it stop only rays of a definite refrangibility analogous to what happens in the absorption of light?

With this view (following a similar mode of operation to that adopted in the last instance) he used successively glasses of different colours, for each of which the distance of the source was varied till a standard effect (about 40° deviation of the needle) was produced on the galvanometer. In this position, in each case, a plate of sulphate of lime was then interposed, and diminished the deviation to about 18° for all the coloured glasses except green, in which case it was to about 8°. When alum was substituted the deviations were reduced in the first case to 8°, in the second to 1°·6. Hence he concludes that all the coloured glasses, except green, produce no "elective action" on heat; green glass, on the contrary, transmits rays more easily stopped than the others.

Connecting this with his other inference, that rays are stopped in proportion to their refrangibility, he instituted another series of experiments to put this to the test. The sources of heat compared were an argand lamp and incandescent platinum, the rays of heat from the former being the more refrangible. The quantities of heat from the lamp and the metal transmitted by the green glass were nearly equal; by all the others, nearly in the ratio of 2 to 1. Hence he infers that green glass is more diathermanous for rays of less refrangibility.

Again, the rays transmitted by citric acid and some other substances, are those only of the greatest refrangibility. They should, therefore, be the least transmissible by green glass. This was found to be the case. Of 100 rays passed through citric acid, all the other glasses transmitted various preparations, from 89 to 28, while green glass transmitted only from 6 to 2.

Without the citric acid, the rays from incandescent platinum were more copiously transmitted by the green glass than by the others.

The whole of the rays of low refrangibility emitted by the platinum, and for which alone the green glass is transparent, had been stopped by the interposition of the plate of citric acid, which had, as it were, sifted it free from these rays.

Hence the author concludes, that "*green glass is the only kind which possesses a* COLOURATION *for heat* (*if we may use the expression*), *the others acting upon it only as more or less transparent glass of uniform tint does upon light.*"

In a subsequent part of the memoir, M. Melloni gives a tabular view of the effects observed in the same manner, of the constant radiations emitted from six different substances, each intercepted successively by 24 minerals and 10 coloured glasses; from which it appears that the transmission is very different, according to the nature of the first medium.

He afterwards describes an experiment with the solar rays transmitted by a green glass, and then intercepted by other media. They pass copiously through rock salt, but feebly through alum. Hence he concludes, *that there are among the solar rays some which resemble those of terrestrial heat;* and in general, that "*the differences observed between solar and terrestrial heat, as to their properties of transmission, are therefore to be attributed merely to the mixture in different proportions of these several species of rays.*"

In a note to this memoir, M. Melloni refers to my original experiment (Phil. Trans. 1825), in which the action of the rays on *surfaces* is observed in *connexion* with their *transmissibility.*

He confirms the accuracy of my result, by a careful repetition of the experiment *with the thermo-multiplier*, but makes no reference to the conclusion I had drawn, viz. the coexistence of two distinct sorts of heat in the radiation from luminous sources, one of which is the same as that from dark sources. He explains the result by supposing the transmitted rays to acquire, in and by the act of transmission through the glass screen, new properties in their relation to the surfaces on which they fall, *i. e.* to the degree of absorption they undergo respectively on a black and a white surface.

He extends the investigation by a table of results of the same kind with a series of screens, both transparent, and of various degrees of opacity. The ratio of the effects on the black and white surfaces is nearer to equality as the screen is more opake.

On this subject there appears a short paper by M. Melloni in the London and Edinburgh Journal of Science, vol. vii. p. 475; to which I replied in the same journal, Jan. 1836.

While referring to my own experiments, I may be allowed to add, that in Dr. Thomson's Treatise on Heat, &c., first edition, the bearing of my investigation was incorrectly represented; and accordingly I pointed this out in the London and Edinburgh Journal of Science, Nov. 1830.

In the second edition of Dr. Thomson's work, which has lately appeared, the author omits all mention of the subject whatever.

Transmission and Refraction of Heat: Forbes.

The subjects of transmission and refraction of heat were taken up by Prof. Forbes; and Melloni's experiments repeated and extended by him; the details being given in the first and part of the second sections of his first Memoir "on the Refraction

and Polarization of Heat," read to the Royal Society of Edinburgh, Jan. 5th and 19th, 1835, and published in their Transactions, vol. xiii.; also in the London and Edinburgh Journal of Science, vol. vi.

The first section contains an account of various experiments with the thermo-multiplier. The principal object was to verify the several points already stated, and especially to determine the degree of accuracy of the instrument. From a comparison of its sensibility with that of air-thermometers, the author concludes that 1° of deviation of the needle corresponds to an effect indicated by about $\frac{1}{50}$th of a centigrade degree. Without increasing the dimensions of the instrument, by which its sensibility would be impaired, he has been enabled, by the adaptation of a small telescope, readily to measure $\frac{1}{10}$th of its degrees; that is, about $\frac{1}{500}$th of a centigrade degree.

One of the most interesting points to which the author directed his attention, was the possibility of detecting *heat in the moon's rays*. These rays, concentrated by a polyzonal lens of 32 inches diameter, and acting on the thermo-multiplier, gave no indication of any effect; so that Prof. Forbes considers it certain that, if there be any, it must be less than $\frac{1}{300,000}$th of a centigrade degree.

He repeated Melloni's experiment of the *refraction of heat by a rock-salt prism*, and was enabled to obtain some approximate quantitative results, giving the index of refraction for heat in this substance, which was a little less than that for light.

In the course of his second section he describes further experiments relative to the question discussed by Melloni, of the separation of the effects due to heat and light, especially the peculiarity (before mentioned) attending green light: he tried flames variously coloured with salts—giving red, yellow, green, and blue light; but found the proportions of rays transmitted by alum, glass, and rock salt to be nearly constant for each substance.

To this part of the subject Prof. Forbes again directed his attention, in a later series of experiments, in which he has obtained numerical results of the highest value. These are detailed in the last part of his third series of Researches on Heat, read before the Royal Society of Edinburgh, April 16, 1838, and published in the Transactions of that body, vol. xiv. To the earlier portion of this memoir we shall refer, under another division of this report.

The third section relates to the *Index of refraction* for heat of different kinds, as compared with that for light in the same

medium. The method of observation adopted is indirect, turning upon the determination of the *critical angle* of total internal reflexion. This was ascertained in a *rock-salt* prism, having two angles of 40°, and one of 100°. The sentient surface of the pile is so placed with regard to the prism, that it continually receives rays coming from the source of heat, after undergoing two refractions and one reflexion, whatever be the angle of incidence, which is effected by a very simple but ingenious mechanical construction. Every kind of precaution to avoid error was adopted. And in this way the author obtained a series of indices "for the mean quality of the heat most abundantly contained in the rays obtained from various sources." These values are given in a table, and are professedly but approximate. Prof. Forbes has, however, subsequently favoured me with an unpublished communication, in which he states, that while the numbers may be regarded as *relatively* correct, in order to become *absolutely* so, they must all be reduced by about ·05. This will give the corrected series of results as follows:—

Source of Heat.	Index of refraction for Rock Salt.
Locatelli lamp	1·521
Do. transmitted through alum	1·548
——— glass	1·537
——— opake glass	1·543
——— opake mica	1·533
Incandescent platina	1·522
Do. transmitted by glass	1·538
——— opake mica	1·534
Brass at 700°	1·518
Do. transmitted by clear mica	1·527
Mercury at 450°	1·522
Mean luminous rays	1·552

From the experiments described in this section, the following general conclusions are deduced:—

1. The *mean* quality, or that of the more abundant proportion of the heat from different sources, varies within narrow limits of refrangibility.

2. These limits are very narrow indeed, where the direct heat of any source is employed.

3. All interposed media (including those impermeable to light), so far as tried, *raise* the index of refraction.

4. All the refrangibilities are inferior to that of the mean luminous rays.

5. The limits of dispersion are open to further inquiry; but the dispersion in the case of sources of low temperature appears to be smaller than in that from luminous sources.

Reflexion of Heat: Melloni.

A short paper, by M. Melloni, entitled "Note on the Reflexion of Heat," was read to the Royal Academy of Sciences, Nov. 2, 1835, and published in the Ann. de Chim. ix. 402, of which a translation appears in Taylor's Sci. Memoirs, Part III. p. 383.

After referring to the experiments of Leslie, to show that the reflexion of heat depends materially on the texture, polish, &c. of the reflecting surfaces, he proceeds to consider what takes place in diathermanous substances, as in rock salt; where, there being no absorption, the difference of the heat transmitted gives the quantity reflected at the first and second surfaces. With other media—as glass, rock crystal, &c.—very thin plates exercise no sensible absorption: hence heat, after traversing a thick plate, being intercepted by a very thin plate, the loss which this occasions is due solely to the two reflexions. These considerations afford the means of estimating the intensities of reflected heat from different substances; and the author, in conclusion, gives a comparative statement of the reflexions from rock crystal and copper.

Analogies of Light and Heat: Melloni and Forbes.

M. Melloni's "Observations and Experiments on the Theory of the identity of the Agents which produce Light and Heat," were read to the Academy of Sciences, Dec. 21, 1835, published in the Ann. de Chimie, No. 50, p. 418, and translated in Taylor's Scientific Memoirs, Part III. p. 388.

In this paper the author combats the views of M. Ampère, who had proposed some ingenious speculations for explaining, on the theory of undulations, the identity of light and heat, the difference of effect being dependent solely on the different wave-lengths; those producing heat being supposed longer than those giving rise to light. Athermanous media, such as water, intercept the longer waves, but not the shorter. Thus the aqueous humour of the eye prevents the retina from being affected by heat as well as light.

The author admits that many phænomena may be sufficiently accounted for by the mere supposition of the difference of wave-lengths; but he mentions some experiments in which he thinks decisively that this will not hold good.

The spectrum formed by a rock-salt prism gives the maximum of heat considerably beyond the red end. On interposing

water of increasing thickness, the maximum successively occurs *in* the red, and thence upwards to the *green*. A similar effect is produced by colourless glasses; but with *coloured* glasses, whilst the *luminous* spectrum is variously absorbed and altered, the place of the maximum of heat *remains unaltered*, and the decrease from it quite regular.

Another experiment consists in interposing a diaphanous body, which absorbs all the calorific, but only a part of the luminous rays. On using in this way a peculiar species of green glass coloured by oxide of copper, the greenish light transmitted "*exhibits no calorific action capable of being rendered perceptible by the most delicate thermoscopes, even when it is so concentrated by lenses as to rival the direct rays of the sun in brilliancy*."

On these points Prof. Forbes has made some remarks in the London and Edinburgh Journal of Science, March, 1836.

Such experiments as these, he justly observes, and indeed many more simple, clearly show that heat is not light, but nothing more. It is a question, then, what is the point really aimed at in these speculations. The author agrees with Melloni in the result, "that one and the same undulation does not invariably impress the senses of sight and feeling at once. The great difficulty is this—to account for the equal refrangibility of two waves having different properties."

New Phænomena of Transmission: Melloni and Forbes.

It appears by the *Comptes Rendus*, that on September 2nd, 1839, M. Arago communicated to the Academy of Sciences a letter by M. Melloni, containing some new and highly interesting experiments on the transmission of radiant heat. He found that *rock salt* acquires, by being *smoked*, the power of transmitting most easily heat of low temperature, or of that kind which is stopped in the greatest proportion by glass, alum, and (according to his view) all other substances.

Upon this point, Prof. Forbes was led to some further considerations, and thence to fresh series of researches "On the effect of the mechanical Textures of Screens on the immediate Transmission of Radiant Heat," an account of which he communicated to the Royal Society of Edinburgh, Dec. 16, 1839.

Upon the above-mentioned result of Melloni, Prof. Forbes remarks, that according to the conclusions indicated in his own Researches (third series), Melloni's view of the interception of heat of low temperature by all substances alike, is equivalent to saying that substances in general allow only the more refrangible rays to pass, or that while rock salt presents the analogy of white glass, by transmitting all rays in equal proportions, every

other substance hitherto examined acts on the calorific rays, as violet or blue glass does on light, absorbing the rays of least refrangibility, and transmitting only the others. And to this rule Melloni now makes out the first exception, or the first analogue of red glass, to be rock salt, having its surface smoked.

Now Prof. Forbes, in his third series, had also pointed out another substance having the same property, viz. mica split by heat. In March, 1838, he had established, by repeated experiments, that the previous transmission of heat through glass, far from rendering it less easily absorbable by mica in this state, had a contrary effect; and also that heat of low temperature, wholly unaccompanied by light, was transmitted almost as freely as that from a lamp previously passed through glass.

Mica not laminated possesses no such property; hence the effect is due to the peculiar mechanical condition of the substance: and hence it occurred to the author, that the effect of smoking the rock salt was owing merely to a mechanical change in the surface; he therefore proceeded to try the effects of surfaces altered by mechanical means.

The surface of rock salt being roughened by sand-paper, it transmitted non-luminous heat more copiously than luminous. Mica similarly scratched showed the same result.

This effect is not attributable to differences in the proportions of heat reflected, for in this respect, at a polished surface, all kinds of heat are alike, as he had before shown; whilst by direct experiment, he found that, at least for the higher angles of incidence, reflexion is most copious from rough surfaces for heat of low temperature, or the same kind which is most freely transmitted; proving incontestably, that the *stifling* action of rough surfaces is the true cause of the inequality.

That there is a real modification of the heat in passing through a roughened surface, as well as through laminated mica, and the smoky film, appears from some direct experiments on heat *sifted* by these different media; which, when transmitted by any one of these, is found in a fitter state to pass through each of the others; and this modification is the more perceptible as the character of the heat is more removed from that which these media transmit more readily; that is, as the temperature of the source is higher. The following results were stated:—

Heat from lamp through smoked rock salt.			Rays out of 100 transmitted.
Direct			36
Previously sifted by another plate of		smoked rock salt	44
do.	do.	laminated mica	44
do.	do.	roughened salt	$40\frac{1}{2}$

The author then proceeded to try the effect of *fine wire gauze* and fine *gratings of cotton thread*; but no difference could be detected corresponding to the different kinds of heat; in every case the interception was proportioned to the fineness of the gauze.

When *fine powders* were strewed between plates of rock-salt, or *fine lines* were ruled upon the surface, or the surface *tarnished* by mere exposure to the air, the easier transmission of heat of low temperature was rendered apparent.

These effects the author considers as evidently pointing *to phænomena in heat, resembling diffraction and periodic colours in light*.

Such was the general sketch of his researches which Prof. Forbes gave at the period above-mentioned. Subsequently (up to March 1840) he continued engaged on the same subjects, and on May 15, 1840, laid before the council of the Royal Society, Edinburgh, a more extended account of the entire investigations, which appears in vol. xv. Part I. of their Transactions, under the title of "A Fourth Series of Researches on Heat." Some remarks by M. Melloni appear in the *Comptes Rendus*, March 30, 1840, on the same subject.

For obtaining a general view of these results, the main point to be kept in sight is the relation which the transmissibility of each sort of heat appears to bear to its refrangibility; and hence the analogy of diathermanous media, which transmit the less refrangible heat, to transparent media, which transmit the red rays of light, the transmission of the more refrangible heat being analogous to that of violet light.

Upon this important point Prof. Forbes enlarges in the introductory part of his memoir; he justly observes that such a generalization carries us forward a step, by teaching us to refer to the quality of *refrangibility* certain properties of heat, which before were connected only with certain vague characters in the nature of the source whence it was derived. Among other things, we find, what was long suspected, but what Melloni first conclusively proved, that it does not essentially depend on the presence or absence of *light*. This refers to his singular discovery of the change produced by the intervention of certain screens.

Heat from *any* source, if it admit of transmission at all through glass, alum, or water, will ultimately have the character of glass-heat, alum-heat, or water-heat, just as light from the sun, or from a candle, becomes red, blue, or green, by transmission through glasses of those colours.

The author gives, as an illustration, the following scale of different kinds of heat, in the order of refrangibility, beginning with the lowest:—

1. Heat from ice.
2. ——— the hand.
3. ——— boiling water.
4. ——— a vessel of mercury under its boiling temperature.
5. ——— metal smoked;—wholly non-luminous in the dark, heated by an alcohol-lamp behind it.
6. Heat from incandescent platina (over a spirit-lamp).
7. ——— an oil-lamp (direct).
8. *Oil-lamp heat* transmitted by common mica.
9. ——————— glass (argand lamp).
10. ——————— citric acid.
11. ——————— alum.
12. ——————— ice.

Melloni having shown that a portion of the heat from a luminous source is transmitted through certain screens, which are wholly opake to light, it became natural to inquire whether the rays so passed possessed the properties of heat from dark sources. This he found to be partly the case, and partly not.

The direct test of examining the refrangibility of the heat-rays issuing from the screen occurred to Prof. Forbes, who found that opake glass and mica act as clear glass and mica do in *elevating the mean refrangibility of the transmitted heat*, an action analogous to that of *yellow* glass upon light. (See 3rd Series, Art. 73, 81, &c.)

But in all this there was nothing exactly equivalent to the action of red glass; this, however, was discovered by Melloni, by the happy suggestion of covering the surface of rock salt with smoke.

These remarks introduce more clearly the main object of Prof. Forbes in following up the inquiry. In the present paper the details of many series of experiments are given, and the more precise results now established may be stated as follows:

I. The peculiar character of the film of smoke on the surface of a diathermanous medium, analogous to redness in glass for light, was found to be possessed by—1. The simple powder of charcoal. 2. Some other dull earthy powders. 3. Surfaces simply dull, or devoid of polish. 4. Surfaces irregularly furrowed, as with emery or sand-paper. 5. Polished surfaces, on which fine distinct lines have been drawn. 6. Transparent mica, when mechanically laminated, which, as a continuous medium, possesses opposite properties.

II. All kinds of heat (i. e. of all refrangibilities) seem affected indifferently by the following media:—

1. The thinnest leaf-gold, *which is impervious to any kind of heat*.

2. Fine metallic gratings, which transmit all kinds of heat

in a proportion probably exactly that of the areas of their interstices.

3. Thread gratings.

4. Most crystalline bodies in a state of powder, in which case they approximate to a condition of opacity for heat.

III. The following substances, in addition to those before known, transmit most heat of high temperature or high refrangibility, analogous to violet light:—

1. Several pure metallic powders. 2. Rock salt, in powder, and many other powders. 3. Animal membrane.

IV. Heat of low temperature is most regularly reflected at imperfectly polished surfaces. It is also, as has been shown above, most regularly transmitted. These facts are in themselves very remarkable, and especially so with reference to the *theory* of heat, and its analogies to that of light, particularly with respect to absorption. Some of these considerations, which bear on the undulatory doctrine, are noticed by the author in § 24.

The curious question relative to the analogies of the action of gratings, &c., to the parallel cases in the interference of light, has been recently illustrated by some mathematical investigations by Professor Kelland; and the author concludes his memoir with some highly ingenious and interesting suggestions for further inquiry bearing on these topics.

Radiation of Heat: Hudson.

At the meeting of the British Association, 1835, Dr. Hudson, of Dublin, communicated some researches on radiant heat, of which notices appear in the Report of that Meeting (p. 163, and Proceedings of Sections, p. 9.). A paper by the same author on the subject is printed also in the London and Edinburgh Journal of Science, vol. viii. p. 109.

In the paper last mentioned, besides making some critical remarks on the results of Melloni and others, the author describes a very simple and effective mode of arranging the apparatus for experiments on diathermancy with the thermo-multiplier, so as completely to exclude the influence of secondary radiation. The source of heat is a canister of hot water, which can be so placed in two different positions that it is exactly at the same distance, and presents the same surface; but in one case the pile receives the heat both direct and secondary; in the other only the secondary, derived from the heating of the screen.

In his communication to the British Association the same author examines principally certain questions bearing on the supposed radiation of cold, and the theory of Leslie. These

were performed by a differential thermometer, and a concave reflector, with a hollow back, so that the mirror itself could be heated to any required point, by filling the hollow with hot water. The source of heat was a canister of water, with one surface varnished, another metallic.

The main results were as follows:—

1. The mirror being at the temperature of the air, and the canister *cooled below it*, the varnished side produced a greater *cooling* effect on the focal bulb than the plain, in the same ratio as that in which it produced a greater *heating* effect when the canister was heated *above* the air.

2. The mirror being heated to 200° Fahrenheit, and the canister at the temperature of the air, both bulbs were so placed as to be equally affected by the heat of the mirror; when the canister displayed a cooling effect, the varnished side being the most efficacious.

3. Again, with the same conditions, except that the canister was heated 10° or 12° above the air, it was placed at different distances; at near distances it showed a cooling effect; at a certain point this ceased, and beyond it, it began to produce a slight heating effect.

4. Some attempts were made to try the effects while the bulb was kept cool by evaporation; the canister being also cooled below the air, the cooling of the bulb was increased beyond what took place when the canister was at the temperature of the air. These experiments were confessedly imperfect, from the difficulty of regulating the evaporation.

The author considers them as favourable to the theory of *the radiation of cold*; he also refers to them as in some degree confirmatory of Leslie's view of pulsation.

The most remarkable result is that of Case 2; it seems to prove that a mirror, when heated, will still reflect rays of heat, thrown upon it from a source of much lower temperature.

The results are viewed by the author as supporting the theory of the radiation of cold. I believe the doctrines of that theory may in all cases be equally well expressed in other language, in conformity with the view to which I referred in my former report, p. 262.

Dr. Hudson has speculated with much ingenuity on another point of great interest, the different radiating powers of different surfaces. Understanding by the surface a certain physical thickness, he conceives the *radiating power to depend on the capacity for heat* of the substance of the lamina, which seems perfectly conformable to the general law of the equilibrium of temperature.

Influence of surface and colour on Radiation : Stark and Bache.

The influence of the *colour* of a surface on its powers for absorbing and radiating heat, is a question which has long attracted notice, and has often been involved in no small confusion, from false analogies. The sun's rays, and, in general, what is called luminous heat, are absorbed by surfaces (*cæteris paribus*) in proportion to the *darkness* of their colours; but it has been too hastily assumed that the same would hold good with non-luminous heat, and still more groundlessly, that the *colour* would influence the *radiating* power of the surface; the *texture* of the surface, however, is known to exert a powerful influence. These distinctions are fully insisted on in my former report.

Since that period, however, the subject has been taken up by Dr. Stark, who, in an elaborate paper in the Phil. Trans. for 1833, details a number of ingenious experiments, which he conceives support the doctrine of the influence of colour, not only on the absorption of dark heat, but even on odours, miasma, &c.

The object of the present report is not controversial; I will therefore merely state, that I discussed in detail Dr. Stark's reasonings, in a paper published in the Edinburgh New Philosophical Journal, October, 1834, where, though allowing the value and accuracy of the experiments, I have expressed my objections to the inferences made from them.

It appears in general that the *texture and nature* of the surface most unquestionably exert a great influence. Now, whereever there is a difference in the *colour*, there *must* be *either* a difference in the mechanical structure of the surface, *or* some new matter added or abstracted. When therefore we consider the changes which thus occur, we cannot infer that the effect is not owing to these instead of to colour as such. The question, however, is a highly curious one, and worthy the most accurate investigation.

Having in some measure called attention to it in my former report, it was with no small gratification that I found the subject had excited interest not only in this country, but also in America; and to Professor Bache (since appointed principal of Girard College) we owe by far the most extensive and valuable series of experiments on this important but difficult point of inquiry: they are given at length in the Journal of the Franklin Institute, November, 1835.

The notices of these experiments which had been published in this country, not appearing to convey adequate notions of their nature or value, I endeavoured to bring them

more prominently forward by some remarks in the Physical Section of the British Association at Liverpool in 1837*. In my former report I had thrown out some suggestions both as to the want of such a series of experiments, and as to the fundamental difficulty arising from the variety of causes which must influence the results; but more especially the differences of thickness in the coatings, which in the ordinary mode of operating could not be estimated, yet must greatly modify the effects.

With reference to the necessity of equalizing the coatings, Mr. Bache refers to an important observation of Leslie, viz. that radiation takes place not merely from the *actual surface*, but from *a certain depth*, or lamina of the surface, the thickness of which is quite appreciable in good radiators, and differs for different substances.

Proceeding upon this fact, the author justly observes, that "the radiating powers of substances would not be rightly compared by equalizing their thicknesses upon a given surface, nor by equalizing their weight; *but by ascertaining for each substance that thickness beyond which radiation does not take place.*"

It is then on the original application of this fundamental idea that his whole series of experiments is conducted.

Upon this principle the first object was to obtain some data as to thicknesses of different pigments necessary to be employed.

The method adopted throughout was to employ tin cylinders of the same size, filled with hot water, and having thermometers inserted through a hole in the top; while their surfaces were coated with the different substances under trial. The radiation was estimated by the observed rates of cooling.

To find the critical thickness of the coating just spoken of, the time of cooling a certain number of degrees was accurately observed, first with a thin coating, then with an additional layer of the pigment, and so on, until it was found that additional thickness did not increase the rate of radiation, but began to diminish it; thus each coating was adjusted precisely to that thickness at which it produced its maximum effect.

Every precaution to ensure accuracy appears to have been most diligently taken, and several series of preliminary experiments are recorded for the purpose of ascertaining the limits within which the precision of the results may be relied on. A standard cylinder, coated with aurum musivum (as being found not liable to tarnish or alteration), was used in all the experiments, and the effect of each coating compared with this under similar circumstances.

* See Report, 1837. Sectional Proceedings, p. 20.

The results of different sets of experiments are given in the tabular form, and apply to coatings of a great variety of substances differing in their chemical nature, as well as in roughness, texture and colour. The following table is extracted as fully exhibiting the general result of all the experiments; the substances being arranged in the order of their radiating powers, beginning with the *highest*.

Nature of Coating.	Colour.	Surface.
Litmus blue.	Blue.	
Prussian blue.	Blue.	Rough.
Ammon. sulphate of copper.	Greenish blue.	Rough.
Peroxide of manganese.	Brownish black.	Not shining, but uniform.
India ink.	Black.	Not smooth.
Bichromate of potash.	Brown.	Streaked: smooth streaks.
India ink.	Black.	Smooth.
Alkanet.	Crimson.	Not shining, but uniform.
Carb. of lead in oil of lavender.	White.	Smooth, not shining.
Sulphuret of lead.	Black.	
Alkanet blue.	Blue.	
Carb. magnesia.	White.	Rough.
Carb. lead in gum.	White.	Smooth.
Carb. of lime.	Dingy white.	Medium.
Vermilion.	Red.	Smooth.
Sulph. baryta.	White bluish.	Rough.
Golden sulphuret of antimony.	Brown.	Smooth, in streaks.
Indigo.	Blue.	Smooth.
Cochineal.	Crimson.	Smooth.
Red lead.	Orange.	Smooth.
Sulph. baryta.	White.	Medium.
Plumbago.	Black.	Not shining, but uniform.
Chrom. lead.	Yellow.	Smooth.
Gamboge.	Olive green.	Smooth, in streaks.
Bisulphuret of tin.	Yellow.	Smooth.

It thus distinctly appears, that through so extensive and varied a range of differences in the state of the radiating surface, *no determinate relation* subsists between the *radiating power*, and either *darkness of colour*, or any other distinctive character of the coating employed; not even its roughness or smoothness.

Repulsive Power of Heat: Powell.

Closely connected with the radiation of heat is its property of exerting or exciting a repulsive force between particles or masses of matter at small though sensible distances.

Such a property was first announced by Libri in 1824; and was further examined by Fresnel (*Ann. de Chim.*, xxix. 57. 107.) and Saigey (*Bull. Meth.*, xi. 167.), but their results seem to have been open to some doubt.

A new interest attached to the subject from the reference made to this property by Prof. Forbes (in a paper read to the Royal Society of Edinburgh, March,1833, and since published in their Transactions, vol. xii.) in explanation of certain vibrations of heated metals first observed by Mr. Trevelyan.

A paper from me was read to the Royal Society, June 19,1834, and printed in the Philosophical Transactions, 1834, Part II. containing an account of experiments on a different principle from any of the preceding, which appeared to furnish a decisive proof of the fact of repulsion.

The essential principle is the employment of the colours of thin plates, as a *measure* of the separation produced between two surfaces, by the repulsive action of heat applied to one of them. I also made observations on several particulars attending the mode of action, both in that paper, and in a communication to the British Association at the Edinburgh meeting*.

Formation of Ice: Farquharson.

An interesting case, in which the principles of the theory of radiant heat are related to the explanation of natural phænomena, occurs in the instance of the formation of ice exclusively at the *surface* of *still* water, but occasionally at the *bottom* of *running* water. This point excited attention some years ago, and was partially discussed by Mr. Knight in the Philosophical Transactions, 1816. Mr. MacKeevor and Mr. Eisdale subsequently investigated the theory, and M. Arago gave a discussion of the whole question in the *Annuaire*, 1833, and in the Edinburgh New Philosophical Journal, vol. xv. p. 128; lastly, a highly curious paper appeared in the Philosophical Transactions for 1835, Part II.

* See Report, 1834, p. 549, and Dr. Thomson's Records of Science.

"On the ice formed under peculiar circumstances at the bottom of running water", by the Rev. J. Farquharson, F.R.S. of Alford, Aberdeenshire. In this paper the author details various new and highly interesting particulars as to the mode of the formation of the spongy masses of spiculæ of ice at the bottom of certain rivers in his neighbourhood, and the peculiar circumstances under which alone it is formed. He examines acutely the several explanations which have been suggested, which he shows are all insufficient to explain the *whole* of the circumstances, and then proceeds to suggest his own theory, which is grounded essentially on the assumption that the *radiation of heat* from substances at the bottom goes on *through the water*; and partly also on the supposed greater radiation from *dark-coloured* surfaces. Neither of these assumptions, it appears to me, are admissible; the former especially is directly at variance with the experiments of Melloni. Some suggestions at least towards a theory not open to these objections, are given by an anonymous writer in the Magazine of Popular Science, vol. i. p. 157.

Division II.—Polarized Heat.

Polarization of Heat: Forbes.

The original statement by Berard, of the polarization of heat by reflexion, and the attempts to verify it, are mentioned in my former report*. In 1833, Melloni tried to repeat the experiment with tourmalines, but unsuccessfully†.

In 1834, Nobili attempted it by reflexion, employing the thermo-multiplier, but without success ‡. The disbelief in such a result, at least with dark heat, seems now to have prevailed generally. Mrs. Somerville, in the second edition of her "Connexion of the Sciences" (in 1833), speaks of it as altogether without experimental proof.

Prof. Forbes took up the inquiry in November, 1834; and in his first memoir, already referred to in Section 2, announced his complete success, after having in the first instance failed from the influence of secondary radiation, which disguised the real effect.

(1.) He proved distinctly the stoppage of a considerable proportion of heat when the tourmalines were crossed, not only with a lamp, but with brass heated below luminosity.

(2.) In the third section of the same memoir, he details his

* British Association Report, vol. i. pp. 262. 276.

† Second Memoir, *Ann. de Chim.* 55. Taylor's Scientific Memoirs, Part I. p. 59.

‡ *Biblioth. Univ.*, Sept. 1834.

researches on the polarization of heat by refraction and reflexion. In the former he employed piles of mica, and through these, found even dark heat very freely transmitted at the polarizing angle. Without (in this stage of the inquiry) aiming at quantitative results, he found in general that the proportion of heat polarized varied with the source in the following order, begining with the highest:—

Argand lamp.
Locatelli lamp.
Spirit lamp.
Incandescent platina.
Hot brass, about 700° Fahrenheit.
Mercury, 500° in crucible.
Water under 200°.

(3.) The polarization of heat by reflexion at the surface of a pile of plates of mica was also established; and with regard to the reflexion from glass, Prof. Forbes has also remarked, that from the known proportions of heat reflected, the quantity, even at the maximum which would reach the thermoscope after two reflexions, would be so extremely small, that no difference of effect in the two rectangular positions could really have been perceptible in the form of the experiment adopted by Berard.

(4.) In the fourth section the author enters on the modifications which polarized heat undergoes by the intervention of crystallized plates between the polarizing and analysing parts of the apparatus; an inquiry suggested by the obvious analogy in the case of light. In the crossed position, when polarized heat is stopped (if the analogy hold good), the *intervention* of a plate of double refracting crystal would *restore* the effect. This apparently paradoxical result was fully verified with plates of mica, and subsequently with selenite and other substances, not only in the case of luminous sources, but even with water below the boiling temperature. Of 157 experiments with three different mica plates, only one gave a neutral and one a negative result. Of these 157, 92 were made with heat below luminosity.

The apparent paradox was increased by the circumstance that a thin plate of mica which "depolarized" but feebly seemed to stop more heat than a thick plate which depolarized more completely.

The main fact was ascertained for the first time on December 16, 1834. The Professor justly censures the use of the term "depolarize," and suggests "*di*polarize" as preferable.

(5.) From the result thus unequivocally established, a train of highly curious consequences follow. We have hence, as direct corollaries, the *double refraction* of the rays of heat by

the mica, and their *interference* according to the same laws as those of light. Hence also follow the constancy of the sum of the intensities of the rays in the rectangular positions, or their *complementary* character, agreeably to the formulas of Fresnel for light. This again involves their *retardation*, according to the well-known principles of the undulatory theory; and hence from Fresnel's formulas we are assured theoretically of the existence of circular and elliptic polarization in the rays of heat, under the appropriate conditions: we have thus also the means of deducing the length of a wave of heat.

The whole of this most important series of investigations was completed between November 1834 and January 1835, and their originality and priority are thus placed beyond dispute. The main *practical* improvement (which led to all the rest of the discoveries) was the employment of the piles of mica for polarizing the heat. In the summer of 1835, Prof. Forbes was at Paris; and finding both M. Biot and M. Melloni sceptical as to his results, he exhibited them with mica piles, which he himself prepared on the occasion, and which he left in M. Melloni's hands.

In these experiments the utmost care was taken to guard against all the sources of fallacy from secondary radiation, &c.; but as Prof. Forbes observed, these always tended to disguise and not to exaggerate the results. One consideration of this kind arising from the mere mathematical question of the different amount of heat which might be radiated from one pile to the other in the two rectangular positions (regarded merely as a mathematical problem), was proposed by myself at the Dublin meeting of the British Association, 1835, but was completely shown to be inapplicable as a practical objection by Prof. Forbes, in a short paper in the London and Edinburgh Journal of Science, November, 1835; and further by direct experiment described in the same Journal for March, 1836.

Circular and Elliptical Polarization of Heat: Forbes.

On the 1st of Feb. 1836, Prof. Forbes announced to the Royal Society of Edinburgh, that he had that day succeeded in establishing the *circular polarization* of heat, even when unaccompanied by light, by *direct experiment*. It has been already noticed, that *theoretically* this would follow from the laws of depolarization. But in the present instance, Prof. Forbes, following up the analogies of Fresnel with regard to the internal reflexion of light, found the very same thing verified with heat by similar internal reflexion *in a rhomb of rock salt*, where the

plane of reflexion is inclined 45° to the plane of primitive polarization.

A short notice of this discovery appears in a paper by the author, in the London and Edinburgh Journal of Science, March, 1836, in which he also states the inference from the same considerations, that the waves are of the *same kind* as those of light, viz. formed by *transverse* vibrations.

In a paper reported in the Proceedings of the Royal Society of Edinburgh, March 21, 1836, and printed along with the second series of Prof. Forbes's Researches in the London and Edinburgh Journal of Science, vol. xii., that philosopher describes some additional results which he has obtained respecting the polarization of heat. These are briefly as follows:—

1st. Heat polarized in any plane, and then reflected from the surface of a refracting medium, changes its plane of polarization in a manner similar to what obtains in light; that is, the plane is on one side of the plane of reflexion up to the maximum polarizing angle, and on the other side after passing that limit. This mode of determining the polarizing angle offers some advantages over the more direct methods.

2ndly. Metals polarize heat very feebly by reflexion. Yet the effect is perceptible, and increases, through a considerable range of incidences, but it does not seem to attain a maximum; in this respect it seems to agree with what Sir D. Brewster has remarked in light, viz. that the maximum is greatest for the least refrangible rays, heat being less refrangible than light.

3rdly. Heat polarized in a plane inclined 45° to the plane of reflexion at silver, has its nature changed, as in light, and presents the conditions of *elliptic polarization*, though the ellipse is much more elongated.

4thly. *Two reflexions* from silver increase the polarizing effect of metals, and an increased tendency to circular polarization under the conditions of the last case. The effect increases with the obliquity of incidence.

All these results have been verified in the case of obscure as well as luminous sources of heat.

On the 15th Feb. 1836, the Keith prize was awarded to Prof. Forbes by the Royal Society of Edinburgh; the Vice-President, Dr. Hope, stating, in the course of a most able address delivered on the occasion, that several members of the council, as well as himself, had personally witnessed the satisfactory verification of the main facts announced, before the medal was adjudged.

Polarization of Heat from different sources: Melloni.

M. Melloni's first memoir "On the Polarization of Heat," was read to the Academy of Sciences in Jan. 1836; it appears in the *Ann. de Chim.* lxi. April, 1836; and is translated in Taylor's Scientific Memoirs, Part II. p. 325.

The author commences with a fair review of the previous investigations on the subject, admitting Prof. Forbes's discovery, but remarking the very small amount of the effect in the case of obscure heat.

He adopts the supposition, that "the different temperatures of the calorific rays are to radiant heat what the different colours of the luminous rays are to light." The latter, he observes, are all equally polarizable, and thus he is led to regard the difference of polarizability in the rays of heat as rather apparent than real. His object then, in this memoir, is to examine the question of the reality of the polarization of heat, and of the equality of the effect in different sorts of heat.

After some considerations on the general nature of the apparatus to be employed, and overcoming the difficulty arising from the small total intensity of the rays, by concentrating them by means of a rock-salt lens, he proceeds to detail his several series of experiments, the results of which he gives in the form of tables:—

Table I. gives the different indices of polarization obtained with nine sorts of tourmalines of different colour, the source of heat being a locatelli lamp.

He then tried the experiment, taking that pair of tourmalines which gave the greatest effect in the last set, with plates of various substances interposed between the lamp and the apparatus. Of these, opake black glass rendered the effect nearly insensible; other solids and liquids of various degrees of transparency produced effects of different magnitude.

In Table II. these results are registered, and the properties of the media, in this respect, were found to follow the same proportion as their diathermancy.

The author considers the difference of the tourmalines in this respect as referrible to the same cause.

Table III. gives similar results with another pair of tourmalines, in which case the proportions are found to differ.

In Table IV. are given the indices of polarization with four different pairs of tourmalines, each employed with different sources of heat; viz. the locatelli lamp, argand lamp, incandescent platina, and copper at 400°. The effect in the latter case was *very* small.

In recapitulating his views, the author refers to the *unequal* absorption of the two pencils in different tourmalines, as causing the differences observed.

A further paper by the same author, on Tourmaline, &c., in the *Ann. de Chim.*, April, 1836, displays much ingenuity, but nothing of peculiar novelty or fundamental importance.

From the *Comptes Rendus*, 1836, i. 194, it appears, that on the 15th Feb. 1836, M. Arago communicated to the Academy of Sciences a letter from Prof. Forbes, announcing his discovery of the circular polarization of heat of the rock-salt rhomb.

At the next meeting of the same body (Feb. 22), MM. Biot and Melloni stated, that in following up Prof. Forbes's experiment, they had found that *quartz possessed the same "rotative" quality for heat as for light.*

Dr. Thomson, in *the second edition* of his Treatise on Heat, &c. (1840), while giving an outline of the discoveries of Forbes and Melloni, has by no means clearly distinguished the share borne by each of those philosophers in the investigation. In particular, with respect to the fact of polarization, he has not given Prof. Forbes the credit so unquestionably due to him for the priority of the discovery. He observes (p. 139), "In the earlier experiments of Melloni, he did not find that the rays of heat were polarized when passed through the tourmaline. But he afterwards found that this conclusion was hasty, and that the tourmaline polarizes heat as well as light. The truth of this statement is shown very clearly by Prof. Forbes. They also polarized heat by plates of mica, and also by reflexion," &c.

These expressions certainly assign the priority to Melloni, as well as an equal share in the subsequent results; both of which we have seen are greatly at variance with the truth.

Further Researches: Forbes.

Prof. Forbes's second series of Researches on Heat was read to the Royal Society of Edinburgh, May 2, 1836, and printed both in the Edinburgh Transactions, vol. xiii., and in the London and Edinburgh Journal of Science, vol. xii. 1838.

The author remarks at the outset, that in his former memoir he had confined himself to the establishment of the general facts of the polarization and *di*polarization of heat, without pretending to accurate quantitative results; he now proceeds, therefore, to a more detailed investigation of the subject, with a view to more precise numerical determinations.

The first section relates to the *methods* of observation employed, and the examination of the values of the degrees of the

galvanometer, which, for the most part, do not indicate equal increments of force. Two tables are given. By the first, the *statical* deviations of the needle are reduced, so as to be measures of the force producing them; by the second, the *dynamical* effect, or arc, moved over by the initial disturbing action, is reduced to the final or statical effect, and thence to the true measure of heat. Several peculiarities attendant on the use of the galvanometer are likewise discussed.

In section 2, the observations formerly published on the polarizing action of tourmaline are confirmed, including the case where heat, entirely unaccompanied by light, was employed. In this case, the author allows, the greatest difficulty was to be encountered.

The third section treats of the laws of the polarization of heat by refraction or transmission. Prof. Forbes expressly observes, that his former results were not held out as numerically precise; and with reference to Melloni's conclusion, "that all kinds of heat are equally polarizable at the same incidence," he confirms his former view of the incorrectness of this inference by a great number of experiments, which show that the heat from non-luminous sources is less polarizable by a given plate of mica, at a given angle of incidence, than that accompanied by light.

These experiments were performed with plates of mica, prepared in a way discovered by himself, to which reference is made (though without describing the process), in a paper before quoted in the London and Edinburgh Journal of Science, March, 1836. The method consists in applying sudden heat to a thick plate of mica, which splits into an infinity of extremely thin films, so thin as to be incapable of retaining heat; these form polarizing piles of great energy. With one pair of such plates the author obtained the following per centages of heat *stopped*, when the planes of refraction of the two plates were in the rectangular position:—

Source of Heat.	Rays out of 100 Polarized.
Argand lamp	72 to 74
Incandescent platina	72
Brass about 700°	63
Do. with glass screen	72
Mercury in crucible at 410°	48
Boiling water	44

These observations were repeatedly made, and verified by others with other pairs of plates. The results agree with the analogy of light; those lowest in the scale being the cases of the least refrangible rays.

In the fourth section the law of polarization by reflexion is discussed. A number of reflecting surfaces were tried, and split mica was preferred. The amount of polarization by reflexion at a given angle, is shown to vary with the source of heat; and it is probable that the kinds of heat do not rank in the same order when the angle is changed. This is the case with light. The change of the plane of polarization by subsequent reflexion, is similar to that which occurs when light is used.

The circular polarization of heat by total internal reflexion, is discussed in the fifth section. This, as before remarked, is a phænomenon really produced in the experiments on dipolarization, if the mica be of a suitable thickness. The direct experiment with rhombs of rock salt, has been already mentioned also. The author here gives a detailed account of them, and the laws of the phænomena deducible, in which the precise analogy with those of light is preserved.

Equal Polarizability of Heat from different sources: Melloni.

Melloni's second memoir on the Polarization of Heat appears to be founded on the second part of his communication to the Royal Academy of Sciences in January, 1836. It is printed in the *Ann. de Chim.* lxv. May, 1837, and the translation in Taylor's Scientific Memoirs, Part VI.

The principal points of these extensive researches may be reduced to the following heads:—

(1.) Referring to Prof. Forbes's Researches, first series, Melloni contends that the differences of polarizability in the heat from different sources there exhibited, are in fact due to differences of secondary radiation from the heating of the mica piles, and subsequently appeals to Forbes's second series, in which he conceives the approach to equality is much nearer, as this source of error was more avoided.

At lower temperatures of the source, he observes, that mica transmits less heat in proportion, and therefore absorbs more: thus the secondary radiation is greater, and the apparent difference in the two positions, or index of polarization, is less.

(2.) He remarks, that Prof. Forbes had found the heat from a dark source, after transmission through glass, to become as polarizable as that from incandescent platina; whereas he considers that the glass plate absorbed the greater part of those rays which otherwise would have heated the piles, and that thus the *apparent* polarization was increased.

(3.) Melloni describes his apparatus, and the precautions for

avoiding secondary radiation, &c., employing piles of *split* mica, and throwing *parallel* rays on them by means of a rock-salt lens, having its principal focus at the source of heat.

He then enters upon the details of his results, in several series, with piles of different numbers of laminæ, and at different inclinations to the axis (the source of heat being a lamp), giving in each case the calorific transmissions in the rectangular positions, or proportions of heat polarized. These are comprised in a series of eight tables, from which the author derives the following conclusions:—

I. The proportion of heat polarized increases as the inclination of the piles is diminished.

II. It attains a maximum at a certain inclination.

III. This inclination is greater as the number of laminæ is increased.

He points out the close agreement of these results with the phænomena of light according to Brewster and Biot.

(4.) The author pursues a further series of experiments on polarization by reflexion, and arrives at the conclusion that the angle of complete polarization by reflexion is very nearly the same for light and for heat.

(5.) If any diathermanous substance be interposed between the luminous source and the piles, the index of polarization does not vary with the substance employed.

This, he contends, proves that the *nature* of the heat does not alter its polarizability.

But also from direct experiment with the radiations from different sources, he makes the same inference, employing, instead of a lamp, incandescent platina, metal heated to 400°, or boiling water, with the same results of uniform polarizability.

He maintains that the difference of polarizability by refraction, arising from the different refrangibility of the rays of heat, is too minute to be sensible.

And for all experiments on obscure heat he proposes to substitute as the source a black glass heated by flame.

(6.) On the depolarization he refers to Forbes's experiments, in which he contends the difference in the rectangular position is very small, but nearly equal with different sources.

He repeats the experiment, with black glass interposed, and finds the effects much greater, and nearly equal in the different cases.

He endeavours to explain Forbes's result of the difference with different sources, by secondary radiation.

Further, by the same method (of interposing a black glass), he finds the equal *depolarizability* of every kind of heat.

In an attempt to pursue the analogy of the *tints* of depolarized light, he acknowledges a failure, and thence considers the interference of calorific rays as not yet proved.

Upon these investigations the following remarks may be offered:—

Under the first head, it should be recollected that Prof. Forbes's first memoir, was avowedly only directed to ascertain general facts, not numerical values; while, with regard to the more precise results of the second memoir, it would appear from the details there given, that the secondary radiation could not affect the results. The screen between the source and the piles was removed only during the few seconds required for observing the first or impulsive arc of vibration, the time of which was wholly insufficient for the conduction of heat; besides, such an effect was disproved by direct experiment, as mentioned above (p. 23).

Of the second point, we shall presently have to notice a complete investigation by Prof. Forbes.

As to the third, with this construction, the heat absorbed by the mica was very trifling; but by the more improved process since used by Prof. Forbes, (p. 27), we have seen this source of error is wholly got rid of. The employment of a pencil of parallel rays does not seem, upon consideration, materially to increase the intensity.

The fourth point is no more than what had been already established by Prof. Forbes.

With respect to the fifth head (including the most important part of these researches), it must be observed, that the differences in the nature of the heat obtained by the intervention of diathermanous substances, are not the same as those between heat from luminous and dark sources. And further, in the experiments mentioned with radiations from different sources, no numerical results are stated. On this point we shall presently notice some more detailed researches of Prof. Forbes.

The sixth point, on the subject of depolarization, is confessedly one of the most delicate in the whole inquiry; but for the same reasons as before, the effect of secondary radiation cannot be referred to as capable of having produced the differences observed.

Unequal Polarizability of Heat from different sources: Forbes.

Prof. Forbes's third series of Researches of Heat appears in vol. xiv. of the Edinburgh Transactions, having been read before the Royal Society of Edinburgh, April 16, 1838. It is also

printed in the London and Edinburgh Journal of Science, vol. xiii.

In the first section the author discusses the variable polarizability of the different kinds of heat. The establishment of this fact was his object in one portion of his second memoir. But these investigations having been objected to by some, and opposite results (as we have seen) obtained by Melloni, the author now repeated the inquiry with every precaution. He rendered the rays parallel by a rock-salt lens, as Melloni had done, and operated at a sufficient distance from the pile: still the differences in the rectangular positions, when different sorts of heat were employed, were as unequal as formerly.

Having varied the experiments in every possible way, he still comes to the same conclusion as before, and gives the following results:—

Source of Heat.	Rays out of 100 Polarized.
Argand lamp	78
Locatelli do.	75 to 77
Incandescent platina	74 to 76
——— with glass screen	80 to 82
Alcohol flame	78
Brass at 700°	66·6
Do. with mica screen	80
Mercury in crucible at 450°	48
Boiling water	44

Melloni's opposite result of apparent uniform polarizability, the author then shows must necessarily arise from the use of mica piles, consisting of a number of distinct plates superposed. Such a thickness of mica modifies heat from dark sources in such a way as to give the portion which it transmits the same character as to polarizability as luminous heat. Whereas Mr. Forbes's results were obtained by the use of mica split by *heat* (as before described), which includes so many surfaces within a very small thickness, that the polarized heat is comparatively unaltered in its character. He shows directly, that these piles transmit heat from a lamp sifted by glass, and from brass at 700°, in nearly equal proportions, while mica ·016 inch thick transmits five times less of the latter than of the former.

The second section relates to the dipolarization of heat. Pursuing the methods given in the first series, the author ascertained the proportion of heat dipolarized by five different thicknesses of mica. From the numerical results thus obtained, he deduces the value of the expression in Fresnel's formula, for

the retardation divided by the wave-length, either of which quantities being assumed, the other becomes known.

In pursuing this calculation, the author finds, that if the numerator (or difference of paths) be assumed to be the same as in light, the length of a wave of heat would result three times as great as that for red light.

Upon this he is led into some important considerations bearing on the theory of undulations as applicable to heat.

Almost exactly similar numerical results were obtained for the heat from an argand lamp, from incandescent platina, and from brass heated to 700°.

At the Anniversary Meeting of the Royal Society of London, Nov. 30, 1838, the Rumford Medal was adjudged to Prof. Forbes, "for his discoveries and investigations of the polarization and double refraction of heat." And in the report of the council announcing the award, a brief but appropriate testimony is given to the value of these researches.

Intensity of Reflected Heat: Forbes.

On March 18, 1839, Prof. Forbes communicated some remarks to the Royal Society of Edinburgh on the Intensity of Reflected Light and Heat.

The theoretical law for the intensity of reflected light, originally proposed by Fresnel, has been confirmed on quite different grounds by the mathematical investigations of Mr. Green and Prof. Kelland. Yet scarcely any attempt has been made toward its verification by direct experiment, except in the critical cases for polarized light originally assumed as the basis of the formula, and a few intermediate photometrical determinations by M. Arago. The uncertainty attending all photometry, led Prof. Forbes to conceive (about the end of 1837) that perhaps some confirmation might be obtained by ascertaining the law which prevails with respect to the intensities *of heat* in the corresponding cases; an analogy which seemed extremely probable from the facts already ascertained, relative to the change of polarization, &c., before noticed.

In December, 1837, he made some first attempts, which were not altogether satisfactory. In the following winter he resumed the subject, and by a suitable apparatus for measuring the angles of incidence, he endeavoured to measure the intensity of heat reflected from surfaces of glass, steel and silver; and though the results can hardly be yet considered completely accurate, yet in the case of glass the approximation to Fresnel's law is closer than any as yet exhibited by *photometrical* observations: while

the observations accord much better with the law of Fresnel than with that deduced by Mr. Potter. In the instance of *metals*, Prof. Forbes considers Mr. Potter's discovery verified, that the reflexion is less intense at higher angles of incidence: he has not yet been able to verify Prof. Maccullagh's inference, that it has a minimum before reaching 90°; and lastly, he observes that the quantity of heat reflected from metals is so much greater than Mr. Potter's estimate for light, as to lead him to suspect that all that gentleman's photometric ratios are too small; this would nearly account for their deviations from Fresnel's law. He has also made some attempts for verifying that law by observations on heat polarized in opposite planes.

Mr. Potter, it is well known, mainly founds his objections to the undulatory theory on the discrepancy between Fresnel's law for the intensities of reflected light and his own photometrical determinations. He has therefore naturally been led into some controversial remarks on Prof. Forbes's results in a paper in the London and Edinburgh Journal of Science, to which Prof. Forbes has replied.

Considering that the whole inquiry is as yet confessedly in an incomplete state, any further observations upon it in this place would be premature.

Conclusion.

In thus reviewing the different points of inquiry which have been of late pursued relative to radiant heat, and the several important discoveries with which that research has been rewarded, I have for the most part preserved, under each head, the chronological order.

The progress of discovery is here, I trust, too clearly marked to allow any real ground for these questions as to priority and originality, which have given rise to so much unhappy controversy between rival philosophers; or to the less open, but equally lamentable manifestations of jealousy, in ambiguous expressions of claims, into which men of science have been sometimes betrayed. The dispassionate reviewer of the history of discovery at once best avoids all such controversial topics, and fulfils the demands of critical justice, by a simple but careful statement of facts.

In the present instance it appears to me that the share of credit due to the distinguished parties respectively, who have cooperated to introduce the discoveries above reported, is sufficiently well-marked, and certainly ample enough in each instance to confer the highest celebrity on those who have borne the chief portion of the labour.

To the continental philosophers belongs the first invention of the instrument, without whose aid none of these investigations could have been accomplished; while all the earliest and most important discoveries of the varying diathermancy of substances; the knowledge of the singular constitution of rock-salt, (which has placed a new instrument in the hands of the experimenter); and the capital fact, disclosed by means of it, the *refraction* of heat from dark sources; together with the very singular phænomena of the changes in the nature of heat, by transmission through certain substances; the remarkable effect of smoked rock salt; the circularly polarizing power of quartz for heat;—all these important discoveries (besides others of minor value) are imperishably associated with the name of Melloni. Our own country as fairly and incontestably boasts, besides improvements in the apparatus and methods, many important results connected with the transmission of heat, accurate *measures* of its refraction, together with some indication of phænomena analogous to those of *diffraction*. In addition to these, the sole and undisputed credit of first unequivocally establishing the grand facts of the *polarization of heat*, even from non-luminous sources, by transmission through mica, through tourmaline and by reflexion; together with the peculiar and invaluable property of mica split by sudden heating (a fact holding a parallel rank with that of the diathermancy of rock salt); the dipolarization of heat; its consequent double refraction and interference; its circular and elliptic polarization; its length of wave, and the production of that wave by transverse vibrations; the confirmation of the circular polarization by the rock-salt rhomb, and the peculiar effects of metallic reflexion; these constitute the unquestionable claims of Prof. Forbes.

On the main point in controversy between these two philosophers, the equal or unequal polarizability of heat from different sources, I have endeavoured to place the facts and arguments clearly before the reader; but must confess my own conviction to be in favour of the *unequal* ratio of polarizability in the radiations from luminous and from obscure sources, while in some instances the apparently opposite results seem distinctly traced to known causes, and in others the equalization of the effects appears to depend on some of those modifications which the intervention of screens produces in the nature of the rays of heat.

The very remarkable class of phænomena just referred to, is perhaps of all the recent discoveries that which seems most singular and anomalous: that the same ray should acquire an entire change of property and nature by and in the act of simply passing through certain media, seems little in accordance with any

conception we can form of such radiation. Is this, we may ask, a real change of constitution, or is it a separation or analysis of the ray into its components?

I have elsewhere remarked, that the terms "luminous" and "dark" heat are of somewhat barbarous appearance; and the objection is more than etymological, especially as we now find the luminosity of the source is not the essential characteristic of the qualities of the rays. And again, in the compound radiation from luminous sources, there is included a considerable portion of "dark" heat as disclosed by its relation to surfaces in absorption.

The relations of heat to *surfaces* in *absorption*, and in the corresponding inverse effects of *radiation*, are among the most important portions of the subject; and I have in consequence been desirous to draw particular attention to the very valuable investigations of President Bache.

The properties which characterize the different species of heat (as we have seen) have been most remarkably developed, and principally studied, in the phænomena of *transmission*. A wide field is open to the experimenter in *connecting* these properties with those belonging to the conditions of surface which produce the absorptive powers of bodies for different species of heat; and these again with those which mark the differences in conductive power, and perhaps also capacity for heat.

With regard to the establishment of a *theory* of the nature of radiant heat, we have seen that the hypothesis of undulations certainly supplies a clue to a vast range of phænomena, especially those connected with polarization.

The question of the identity of the heating and illuminating radiations seems clearly negatived by many experiments, if we mean it to apply in the sense of one physical agent. But if we refer to the possibility of accounting for the different effects by sets of undulations of the same ætherial medium differing in their wave-lengths, this probably presents fewer difficulties than any hypothesis of peculiar heat.

We may perhaps suppose some other element besides the wave-length to enter into the explanation: or while we find that the heating effect is due to waves of greater length, it may also be true that the intensity or accumulation of waves, which is necessary for producing the sensation of light, follows a very different and much higher ratio than that requisite for producing heat; and that this latter effect may be produced in the highest intensity by longer waves of the same ætherial medium, but not sufficiently accumulated to impress our visual organs.

The difference in the polarizability of heat from different

sources is not explained by the slight difference of refrangibility; and Prof. Forbes is of opinion that we must in consequence look for its solution to a mechanical theory of heat in some respects at least different from that of light. It is even a question of some difficulty, why any portion of the heat should not be subject to the law of polarization which the rest obeys, unless we suppose the heating effect to be of so complex a nature, that some part of it only is properly due to *rays* analogous to those of light, while the other part of the effect is produced by a mode of action altogether different.

To any such questions, however, we are hardly yet in a condition to give a satisfactory answer; but among the numerous points open to inquiry, I have dwelt more particularly on those which appear to me pre-eminently to require more extended investigation before we can hope to obtain materials for constructing any substantial and unexceptionable theory.

Supplementary Report on Meteorology. By James D. Forbes, *Esq.*, F.R.S. Sec. R.S. Ed., *Professor of Natural Philosophy in the University of Edinburgh.*

[A Summary of the Contents will be found at the end of this Report.]

1. The present Report on Meteorology is intended to be supplementary to a former one on the same subject, drawn up by me eight years ago, and printed in the Second Report of the British Association.

2. It was in the contemplation of those persons who assisted in organizing the Association at York in 1831, that the reports on the progress of science should be essentially *progressive*,—that the same authors, or others, should be engaged to continue from time to time their sketch of the ever-varying point of view which each science presents, not merely with the intention of registering something like a compendious history of facts, but likewise of philosophizing in some degree upon the new character which, during the elapsed period, science may have assumed,—of indicating the success, or not less instructive failures which may have occurred in attempts to carry forward our knowledge in the lines of direction indicated in previous reports, as the most hopeful or important, and of calling attention to new fields of discovery, new instruments of research, or the collateral suggestions which may often be derived from the progress of the affiliated sciences.

3. My aim in the following report will be—*first*, to sketch the broad features of the science as it stands; *secondly*, to give the bibliography of the subject within a definite period of years; and *thirdly*, to point out the more conspicuous deficiencies of our knowledge, and the *kind* of observation, experiment or reasoning by which these blanks may be supplied. In fulfilling this last and responsible duty, the reporter does not lay himself open to the charge which has sometimes been very needlessly preferred, that he is only attempting to stimulate where there is more than energy enough,—that the tide of science is in such full flow, that any external or partial impulse does no more than propagate a local disturbance; that the grand prime-movers,—the wants, ambition, and restless curiosity of men,—would act just as strongly, without assistance or direction, in

urging the mighty mass steadily forward in its regulated course; and that at the same height precisely, and at its appointed hour, will its proud waves be stayed. Let us remember that, even admitting the sufficiency of labourers and of enterprize, it is necessary that this power should receive a useful direction, that it may not be wasted by misapplication, enfeebled by diffusion, and degraded to unworthy ends. He who points out distinctly where energy may be usefully applied, —who concentrates scattered and disunited forces,—who holds up continually to view the demands of science as worthy of individual pursuit and national encouragement, in opposition to the popular call for the bare *quantum* of information gleaned from desultory experience, which may penuriously supply the exigency of the moment,—he it is who contributes to the ultimate economy of mental labour, to the advancement of substantial knowledge, and, it may be, to raise the intellectual character of his country.

4. Impressed with these views of the possible utility of reports, such as those which the British Association has from time to time required of its members, I attempt the task of continuing my report with more reluctance than I felt in commencing it; and, lest more may be expected than I am at all prepared to fulfil, I will premise, that I shall feel myself at liberty to select, for fuller illustrations, those departments of the widely ramified science of meteorology on which I may have some matured suggestions to offer, without in the least degree inferring a depreciation of those topics which the limits, both of time and space, to which I am confined, prevent me from dwelling upon in equal detail.

5. It is not proposed, then, in this report, to supply nearly all the deficiencies which, I am very sensible, exist in the previous one, nor yet to enter at length upon subjects which in it were comparatively untouched, but rather to select such topics as bear most upon general principles, and afford room for practical suggestions; giving, as far as may be, a bibliography of meteorological science in its wider acceptation, particularly during the last eight years.

6. And here I would acknowledge the useful suggestions and information which I have received from the excellent German edition of my former report, translated and most materially amplified by Mahlmann*, in which many involuntary omissions have been ably supplied, and subjects purposely passed

* *Abriss einer Geschichte der neuern Fortschritte und des gegenwärtigen Zustandes der Meteorologie,* &c. übersetzt und ergänzt von W. Mahlmann. Berlin, Lüderitz, 1836, pp. 248.

over with little notice, copiously illustrated. To this work (which is to such a degree original, that I may be allowed to recommend it,) I shall frequently be indebted in the course of these pages.

7. The useful *Repertorium* (or Analytical Index to Scientific Literature) of Fechner, has been succeeded by the ably-conducted work of Dove and Moser, under the same title, in which it is proposed, somewhat after the manner of the British Association Reports, to analyse the various publications connected with physical science, so as to present, in a cycle of five or six years, a digest of all that has appeared on each subject in the preceding period. The third volume of Dove's *Repertorium**, which has lately appeared, contains a valuable analysis of works on one portion of meteorology.

8. To Professor Kämtz of Halle, beyond all comparison the most devoted meteorologist of the present day, we are indebted for the most laborious systematic compilation which has yet appeared upon the subject†; a compilation, however, which includes many important contributions and generalizations of his own, and which is as much distinguished by copious references to the works of all who have preceded him, as many works of the English and French schools are by the total omission of such literary justice. In the first volume we have the subject of Temperature generally discussed, and that of Wind and of Rain. In the second, is the most complete collection of facts anywhere to be found, on the laws of diurnal and annual changes of temperature, on isothermal lines, and the proper temperature of the globe, followed by a chapter on barometric oscillations, and another on atmospheric electricity. The third volume is chiefly devoted to optical meteorology and terrestrial magnetism. This is the only work we have which can properly be considered as a system of meteorology (with the exception, perhaps, of the article Meteorology in the Encyclopædia Metropolitana, mentioned in the former report).

9. The attempt to systematize and direct meteorological observations within the last eight years, is in nothing better shown than in the various "Instructions for Observers," which have appeared during that time from various and very influential sources. Some of the special contents of these instruments we shall have occasion to notice, as well as the spirit which they are likely to impress upon future systems of observation, and

* Berlin, Veit & Co., 1839, 8vo.

† *Lehrbuch der Meteorologie*, 8vo. 3 Bände, 1831—1836. The same author has more lately published Experimental Physics, and Lectures on Meteorology.

on national undertakings; in the mean time we may enumerate the principal ones by their titles.

I. Instructions pour faire des Observations Météorologiques et Magnétiques, par A. T. Kupffer. St. Petersbourg, 1836, 8vo, pp. 77. Chiefly instrumental details; including, however, a theory of the wet bulb hygrometer.

II. Instructions for making and registering Meteorological Observations in Southern Africa. Drawn up under the direction of Sir John Herschel*.

III. Instructions pour le Voyage de la Bonité; Physique du Globe, par M. Arago, Comptes Rendus de l'Académie des Sciences de Paris, I. 380. Annuaire du Bureau des Longitudes, 1836.

IV. Instructions pour l'Expédition d'Algérie, 1838. Par le même, Comptes Rendus, VII. 206.

V. Report of the Committee of Physics and Meteorology of the Royal Society, on the Objects of Scientific Inquiry in those Sciences; drawn up for the Antarctic Expedition of 1839. Instructions for making Meteorological Observations, pp. 53—79; with an appendix of Tables.

10. But of all periodical literature, the work which gives the fairest representation of the progress of physical science north of the Alps, is Poggendorff's *Annalen der Physik*, which, even as a bibliographical compendium, is invaluable. In the numerous volumes of this admirably edited work, are to be found the best papers published on meteorology, and all the kindred sciences, whether in Germany, France, or Britain. The editorial skill and impartiality with which this work is conducted, render it most deserving of support in every country; whilst the high scientific standard, according to which articles are admitted or selected, is highly creditable to Germany; where alone, perhaps, in Europe, so learned a work would find adequate support†.

11. I regret very much that, from the difficulty of procuring

* These instructions, printed by the South African Institution, have, I believe, been republished in the Journal of the Royal Geographical Society. See also Instructions for Observation, and Suggestions for Meteorological Inquiry, in the first volume of the Transactions of the Meteorological Society of London, 8vo.

† M. Poggendorff, not satisfied with translating the best foreign memoirs of the day (to facilitate which he has recently added an annual supplementary part), has, on various occasions, published, for the first time in German, older memoirs, of considerable length and difficulty, for the purpose of presenting his readers with a complete view of the progress of any science, without searching further than his own pages. Thus, he has lately translated Fresnel's Memoir on Diffraction, and Sir James Hall's papers on the Consolidation of Strata.

with the least regularity the periodical literature of Italy, I am unable to present any connected view of what has lately been effected in that country for meteorological science. The observations of Sig. Cacciatore, of Palermo, on a uniform system of standards for meteorological observations*, are among the few that have come to my knowledge. Let us hope that the recently founded Association of Italian Philosophers will do something towards supplying the want of information under which we labour of the actual progress of science in that country†.

12. Since the last Report on Meteorology, Mr. Luke Howard has published a second greatly enlarged edition of his Climate of London‡, which deserves to be considered, not as a mere journal of observations, but in some degree as a systematic work. Professor Stevelly, of Belfast, promises an elementary treatise, the first in our language. M. Quetelet, of Brussels, has published a full account of the history of Meteorology in the Pays Bas§, to which, however, his own contributions are by far the most important.

13. This might appear the natural place for enumerating the public establishments lately founded for cultivating (amongst other things) the practical part of meteorology. When, however, we shall have considered a little minutely the condition of the science in its several branches, we shall be better able to appreciate their value, and suggest measures for their extension. (See Suggestions at the close of this Report.)

14. I proceed now to the different departments of meteorology, nearly in the order in which they were discussed in my former report‖. I have already stated (4.) why I shall hold myself at liberty to enlarge more upon some topics than others, or even restrict myself occasionally to a mere enumeration of

* *De redigendis Observationibus Meteorologicis.* Panormi, 1832.

† In the *Bibliothèque Universelle de Génève*, is generally to be found a fuller notice of Italian papers than in other journals published north of the Alps. This practice might, with advantage, be yet further extended.

Since this was written, I made it my particular business, during a visit to London, to search for Italian Scientific Journals. In none of the public libraries where I made application, as most likely to obtain such works, could I find that Italian Journals are regularly subscribed for or received! A new Tuscan Scientific Journal is recently announced, with the names of Amici and Savi amongst the editors.

‡ 3 vols. 8vo, Lond. 1833.

§ *Aperçu Historique des Observations de Météorologie, faites en Belgique jusqu'à ce jour*, 4to, Bruxelles, 1834.

‖ I take this opportunity of returning my thanks generally for the communication of valuable meteorological papers, in a detached form, from the respective authors, which, for the most part, will be found cited in the following pages.

memoirs, which may assist the researches of others, and enable them to draw their own conclusions.

I.—Temperature.

15. Meteorology may, in some sense, be considered as a mere branch of the science of heat in its widest application. Were our globe and atmosphere in a uniform state with regard to heat, and not subjected, by astronomical and cosmical laws, to perpetual and material changes in the distribution of temperature in its solid, fluid, and gaseous parts, the simplest considerations would suffice for the solution of the few problems which could then be called meteorological.

16. It is to the different inclination of the solar rays, that we trace the effect of climate varying with latitude, and of climate varying with season. It is to the unequal absorption and radiation of heat by seas and continents, that we ascribe the curious inflections of the isothermal lines, and the characters of moderate and excessive climates. It is to the combination of these causes with the rotation of the globe, that we attribute all the phænomena of wind, from the steady monotony of the Trades, to the capricious changes of higher latitudes, the Tornados of America, and the Typhoon of the Chinese seas. It is to the mechanical transport of great masses of air due to change of temperature and consequent expansion, that we look for the explanation of most of the irregular, and several of the periodical barometric fluctuations. Lastly, it is to the varying conditions of temperature proper to the day and night, to one season and another, in high latitudes and low, that we look for principles to guide us in the difficult, but important determination of the hygrometric elements of our atmosphere, the ceaseless modifications of that fluctuating ocean of vapour which floats independent of, and unobstructed by, the permanently elastic envelope of our globe, which (though comparatively unheeded by us) is subject to all the variations of pressure and temperature of the common atmosphere, but through limits far wider, and to changes of physical condition, which the other, from its permanent character, never presents.

17. If we choose, then, to consider the grand meteorological problem for a moment synthetically, instead of analytically—I mean, by regarding the known causes which influence climate, and applying to these the laws of distribution and communication of heat, which are deduced from laboratory experiments, and from the first data or experimental axioms of that science,—we have, at least, the advantage of perceiving the magnitude, interest, and definitiveness of the problems with

which meteorology, in the philosophical sense of the term, is conversant. Those who limit themselves to a few daily mechanical observations of the barometer and thermometer, or who even apply the results of these simple, but (if well conducted) important observations, are little aware that the science they cultivate is capable of giving definite answers to questions which might seem further removed from human apprehension than even the problems of physical astronomy, such as the condition of the interior of our globe with respect to temperature,—and in some degree its history as regards periods of geological convulsion,—the whole measure of solar heat received by our globe in a given time,—the condition of the highest, and for ever inaccessible parts of our atmosphere,—the temperature which reigns in the vast regions of space, remote from the influence of any planet or satellite, however small, whose presence and proper heat would yet influence such an experiment;—these are amongst the great cosmical problems which we do not mean to say *have been* solved, but which there is little reason to doubt that we are in the fair way of one day being able to solve by instruments such as we now possess, with the aid of theoretical investigations identical in kind with many which have been completely mastered.

18. Of *Instruments*, those which are most called for are such as acquaint us with certain physical constants, or approximate constants, which determine for our globe and its atmosphere the *particular* application of the *general* laws of the Conduction and Radiation of Heat. Of *theoretical Investigations*, we require such as shall solve with sufficient generality the problems with which we have to deal, but stripped of those exuberant claims to mathematical precision which cramp their application and discourage those who know how far we are from even the chance of *ever* attaining to a degree of accuracy which such niceties pre-suppose. The theoretical investigations of most use, then, are those which, taking the problem in a general way, show exactly upon what arbitrary constants the determination (for instance) of the climateric condition of any point of the globe at any moment depends. This is a task of no small difficulty, even in the simplest form in which it can be put.

19. It infers a knowledge (1) of the fundamental laws or axioms of the science of heat (such as the law of expansion, variation of specific heat with density, conduction, radiation). (2) Of all the physical circumstances which can possibly influence the temperature of our globe, that is, the communication of heat to, or abstraction from it (I mean their existence, not their de-

termination), such as solar radiation, the proper heat of the earth, the proper heat of the atmosphere, the proper heat of space. (3) Supposing these preliminaries rightly assigned, next comes the arduous mathematical investigation of the way in which the unknown constants which represent these various energetic sources of modification, enter into the final expression of atmospheric temperature, or whatever be the particular problem under consideration. (4) For the determination of the constants (which are supposed to be reduced to the least number of independent elements), the analyst is further bound to mould his formulæ into such a shape as to insulate a certain number of the constants in such a way that they may be determined by direct physical experiment; whence the others not so determinable may be inferred by the principle of exclusion, which assigns the difference between the sum of effects due to causes already estimated, and the observed effect, to a remaining cause (such as the temperature of space) which does not admit of such direct estimation.

20. The duty of the experimentalist is thus clearly defined. Perhaps the most important observations which man can make for furthering the theory of the universe, are such as no general sagacity, no patient attention to mere facts as they are presented in the course of nature, could possibly have indicated. And it is the most satisfactory and encouraging proof that such a synthetic mode of treating the problem is not an injurious or an illusory one, when we find many concurrent observations set on foot in the way which theory has indicated, leading under varying circumstances to a common result. Such instances are not uncommon, and will fall to be noticed hereafter*.

21. It is plain, then, that there are three departments of science which must go hand in hand to perfect a mixed science like that of meteorology. *First*, the experimental philosopher must advise generally on the experimental axioms, and on the modifications which they are to receive in order to allow for causes which yet do not admit of nice numerical estimation; he must further be fully persuaded that *no energetic cause* of modification has been left out of account; for in so delicate an inquiry, where the principle of exclusion is to be acted upon, enormous errors would result from any oversight in this stage

* Such, for instance, as the geometrical diminution of the range of animal temperature beneath the surface of the ground, as we descend in arithmetical progression: the *uniform* retardation of epoch in the same circumstances, and perhaps we might have added a few years ago, the agreement of several different methods of approximation to the actual temperature of space. See former Report, p. 203, and Mahlmann's Translation, p. 14.

of the process. *Secondly*, the mathematician requires the utmost resources of his analysis to obtain in a definite and tangible form the resultant action (we will suppose that temperature is the question) of all the heating and cooling influences upon a certain point, whose coordinates are given (including elevation in the atmosphere, or depression below the surface), and at a particular instant of time. And in this investigation he will, as we have said, chiefly show his skill in the precision which he gives to his results, the judgement with which he introduces needful approximations at that stage of the investigation which shall tend most to simplicity, and in the exhibition of his results in forms adapted to experimental verification. Then follows the duty, in the *third* place, of the observer, or practical meteorologist, which is to follow the indications which theory assigns for the determination of data, and for which the methods will be indicated by a competent knowledge of experimental philosophy, and even by prolonged tentative researches in the laboratory. It is not unoften the provoking result of the labour expended by the two first sections of investigators, that the whole problem is found to turn upon certain quantities, whose nature is perfectly well understood, but which are, and threaten for ever to remain perfectly unknown. I need hardly stop to point out that such a threefold division of labour is to be found in many other sciences, and notably at present in that of magnetism. A right appreciation of the steps leading to the solution of such complex mixed problems, which in fact involve a whole science, is the first step to their solution; and we commonly find that this is performed by the appearance of some master mind, capable of seizing the question in all its extent and under every one of these forms—depending on a versatility of mental endowment of no common order. This is what Newton did for the science of gravitation, what is now being done by the union of many for the science of optics, and what Gauss has pre-eminently done for the science of magnetism.

22. It will conduce to clearness if it is understood, that so far as possible, in what follows, we shall keep in view these different aspects of meteorological science; and combining, as on a former occasion, the bibliography with the general detail, I shall proceed to the different parts of the science of Temperature somewhat in the order adopted in the last report.

A. *Thermometers**.

23. *Fixed Points.*—Legrand† has studied once more the vexed subject of the rise of the thermometric zero point. He finds that the pressure of air has no influence, thus confirming the observations of Bellani; the molecular change in the form of the bulb is therefore the remaining cause, and this is confirmed by finding that it depends on the nature of the glass; not occurring (according to the author) in *Crystal*. Now if by Crystal is meant, as I believe to be the case, *Flint Glass*, this observation is at variance with that of other observers, flint glass being generally used for thermometers in this country. Since writing the last report, I have myself found the following displacement of zero in thermometers all warranted standards by the following makers—Troughton and Simms (two), Adie, Crichton, Collardeau:—

+ 0°·56, + 0°·33, + 0°·41, + 0°·54, + 0°·35, Fahrenheit.

24. *Correction of Scale.* When the points are fixed and the thermometer graduated, the degrees may be examined by the method of Bessel‡. Rudberg has proposed another founded on similar principles§, and I have given an account of a method employed by myself, and attended, I think, with considerable practical advantages, in the introduction to a paper on the Temperature of Hot Springs‖.

25. Every one must have noticed the difficulty of reading thermometers quickly and correctly when the tube projects much in front of the scale, owing to an evident error of parallax, which it requires some experience to avoid. A particularly ingenious method of correcting it has been communicated to me by M. Valz, the eminent astronomer of Marseilles, which though unpublished, I trust he will forgive me for mentioning. By plunging two-thirds of the diameter of the tube into the material of the scale so that the plane on which graduation is made is advanced in front of the mercurial column to the amount of one-third of the radius of the tube, it may be shown that the error of refraction will exactly correct the error of parallax.

26. For *self-registering* thermometers for maximum temperatures, such as are now in demand for experiments on deep Artesian Wells, we have the overflowing principle of Cavendish and

* See last Report, p. 208. Mahlmann, p. 25.

† *Comptes Rendus* (Paris), iv. 173.

‡ Berzelius, *Jahresbericht*, xv. 70, quoted in Poggendorff's *Annalen*, xxxvii. 376.

§ See a full illustration of Bessel's method in Kupffer's "Instructions," p. 5.

‖ Philosophical Transactions, 1836, p. 571.

Magnus* revived by Walferdin, and his instruments are usually employed in Paris†. The overflowing principle has been used (in the same way as in Wollaston's thermo-metrical barometer) for constructing a thermometer sensible to small change of animal heat by Dr. Marshall Hall‡. Jurgenson, the chronometer-maker of Copenhagen, has proposed a clock for estimating the mean temperature of limited periods, in which the compensation shall be inverted, and the natural effect of temperature on the rate of an uncompensated clock exaggerated§.

27. Several other methods or new applications of known principles have been proposed for the measure of temperature besides that of expansion commonly employed. The extensive introduction of the thermo-electric pile of Nobili and Melloni, in delicate researches on radiant heat, has suggested the use of the same principle in other cases. Indeed it seems peculiarly adapted for ascertaining the condition of inaccessible points in respect of temperature. M. Peltier, of Paris, I believe, first proposed the application of long wires of heterogeneous metals to ascertain at a distance the temperature of their point of junction, however distant. The method is briefly this: suppose two wires of copper and iron respectively, and of equal lengths, laid side by side and soldered at each end. Let one of the wires be cut, and a galvanometer introduced into the open circuit thus made. It is well known that the galvanometer needle will not stand at zero under these circumstances, unless both solderings have a common temperature. As the temperature of one exceeds or falls below that of the other, the index will move in one or other direction, and in a well-constructed instrument the deviations will be almost exactly as the variations of temperature ||. Thus, one junction of the wires being plunged in water of known temperature, and the positive or negative deviation of the galvanometer being known and converted into thermometric degrees, the temperature of the other soldering (which may be inaccessible and removed to a considerable distance) becomes known. This very ingenious arrangement was shown to me in June, 1835, by M. Peltier, whose acquaintance I owe to the attention of M. Elie de Beaumont.

28. The application of the thermo-electro-magnetic principle becomes easy in very many cases. It has been proposed for pyrometers by M. Pouillet, who has compared the march of such

* First Report, p. 209. † *Comptes Rendus* (Paris), ii. 505, 619.

‡ British Association Reports.

§ *Comptes Rendus*, iii. 142. Compare First Report, p. 213.

|| I am aware that this position has been controverted. I am satisfied, however, of its general truth from careful experiments.

an instrument at high temperatures with that of an air pyrometer*, and at very low temperatures obtained by means of M. Thilorier's happy discovery of the solidification of carbonic acid with air and alcohol†.

29. MM. Becquerel and Breschet have employed the same method for the determination of the temperature of water at great depths by sinking the experimental junction of the wires. As may be supposed, however, in such cases, great attention is requisite to prevent the *slightest* chemical action, which would develope its proper current. They made their observations on the Lake of Geneva‡.

30. The same ingenious experimenters have applied this method of measuring temperature to the living animal fibre, by thrusting a compound needle into the muscular tissue, and with very curious results§. M. Dutrochet has lately applied the same method to ascertain the proper temperature of plants, a yet far more difficult inquiry||. His experiments have been fully corroborated by MM. Van Beek and Bergsma¶.

31. I have applied M. Peltier's apparatus for the very obvious purpose of checking the zero point of thermometers sunk in the ground to such a depth that their scale can never be re-examined. For this purpose, along with a thermometer 24 French feet long**, I sunk a thermo-electric pair of iron and copper, completely defended in all its length with a casing impervious to water, and its indications have been generally satisfactory. I had hoped that, by the use of wires of sufficient thickness, the thermo-electric current might be communicated from great depths. From experiments which I have made, I am inclined to think that their use must be very much limited in this respect, on account of the rapidity with which the energy of the circuit

* *Comptes Rendus* (Paris), iii. 782.

† Ibid, i. 513. Professor Muncke, of Heidelberg, has investigated with great care the law of dilatation of alcohol, and the result gives for *ordinary atmospheric temperatures*, a value very sensibly different from the *mean* dilatation commonly received from Dalton's experiments. He has also given the result of several series of observations on other fluids, and given formulæ of expansion for each.—Petersburg Transactions—Paper read 5th Sept. 1834. M. Rudberg has re-examined the expansibility of dry air and gases (Poggendorff's *Annalen*), and he finds an expansion of only ·364 or ·365 between freezing and boiling water instead of ·375, as was given very nearly both by Dalton and Gay Lussac. The scientific world will, no doubt, hesitate a little to adopt the new determination of this important element, even with all possible respect for M. Rudberg's known skill as an experimentalist.

‡ *Bibliothèque Universelle, Nouvelle Série*, vii. 173 (1837).

§ *Comptes Rendus* (Paris), i. 28, iii. 771.

|| Ibid, viii. 695, 741, 907. ix. 613. Temp. of Insects, ix. 81.

¶ Ibid, ix. 328. ** See below. Art. (96.)

diminishes with the length of the conducting wire. Some advantage is undoubtedly gained by using two or three pairs, acting simultaneously, instead of one. Wherever distant comparisons are intended, it is of great consequence to have a *standard thermo-electric combination*, by which any change in the sensibility of the galvanometer may be tested.

32. A method of determining the temperature and pressure of the atmosphere depending on very different principles, has lately been proposed by M. Arago*. It depends on the known optical principle, that if a pencil of light radiating from a small and distant source be divided into two parts, and one of these be in the least degree retarded more than the other, coloured fringes will appear when the two pencils are re-united and suffered to fall upon a screen or received on an eye-piece. If by any arrangement, whether of reflexion or refraction, these bands have been *already* formed, their breadth and aspect will be changed by such a retardation of either component pencil. Now air rarefied, whether by heat, diminished pressure, or the intermixture of vapour, acts less energetically in retarding light; consequently a tube with glass ends, filled with such *modified* air made to transmit one pencil, whilst the other passes through a precisely similar tube of *standard* air, will exhibit by the production of movement of the fringes very minute changes in its physical condition. It remains to be shown, however, by what mechanical adaptations M. Arago proposes to make this delicate experiment susceptible of general application. This he proposes to point out in a future memoir†.

33. The comparison of ordinary thermometers with standards is often a matter of great importance, and too little attended to. The increasing demands of science require a proportionable increase in the consistency of instrumental indications; not so much indeed for ascertaining the temperature, as in many other experiments connected with the temperature of the ground, rivers and hot springs. Travellers should seize every opportunity to verify the freezing points of their instruments, and this is an easy matter; but to compare thermometers at temperatures above 100° F., is a practical problem of far greater difficulty than is commonly imagined. Plunging them together in laboratory vessels of hot water is a most unsatisfactory process, even if the sensibilities of the instruments be pretty equal. If they are very unlike, it is all but impossible, although the correction for the gradual cooling of the medium becomes then a pretty mathematical problem‡. Where the investigation is an important one,

* *Comptes Rendus* (1840). † Ibid.

‡ Fourier, *Théorie de la Chaleur*, p. 357, and Kelland's Theory of Heat, p. 84.

or many instruments are to be compared, constant sources of heat, natural or artificial, cannot be too carefully sought. Bark pits, natural hot springs, even the waste hot-water of steam-engines, and the boiling point of some liquids, such as alcohol, may be usefully employed*.

B. *Atmospheric Temperature*†.

34. Under this head we consider the temperature of a given spot at different times. These variations are diurnal, annual, and those of long period.

35. A summary of valuable facts on this subject may be found in Kämtz's *Meteorologie*‡ and Dove's *Repertorium*§. We can only point out a few general facts of especial importance.

36. The general practice in Germany of expressing periodic changes of temperature by series of the form

$$T = A + B \sin (x + C) + D \sin (2\,x + E) + \&c.,$$

where x is the hour angle, or the fraction of a year, is attended with considerable advantages, especially for the purposes of interpolation; and if this has sometimes been carried perhaps too far, yet the reductions are on the whole very superior to those in use in this country.

37. The value of *hourly observations of temperature* seems now to be fully admitted, and the *two-hourly* meteorological observations connected with the recent magnetic expeditions fitted out by the English government, are likely to be of the highest importance for science. In the mean time we may quote the following important contributions, in addition to those specified in the former report. 1. Goldingham's hourly observations, three times a month at Madras ‖. 2. Brandes's observations at Salzuflen (lat. 52° 3′ N.), made every hour in the year 1828 ¶. 3. The observations which, at the earnest suggestion of the Meteorological Committee of the British Association at its first meeting at York, have been so ably and zealously carried on hourly for seven complete years, under the direction of Mr. Snow Harris at Plymouth. The means have been regularly

* I have found by the most careful experiments that the temperature of the vapour of impure alcohol remains surprisingly steady, which was before remarked by Hugi (*Alpenreise*, Solothurn, 1830), but it is not the same with æther. There are some interesting experiments on the constancy of the temperature of vapour from saline solutions in the late volumes of Poggendorff's *Annalen*, especially by Rudberg, xxxiv. 527.

† See former Report, p. 210. Mahlmann, p. 31. ‡ Vol. iii. p. 342.

§ Vol. ii. p. 1. ‖ Madras Observatory Papers, calculated by Dove.

¶ *Archiv der Pharmacie*, Reihe ii. Bd. xi. 1, quoted in Poggendorff, xli. 635, and Poggendorff's Remarks, xli. 630. Compare *Comptes Rendus* (Paris), i. 264, and Dove's *Repertorium*, iii. 345.

calculated and communicated to the Association in two reports on the subject*. 4. A most interesting series of observations made every two hours in the inhospitable regions of Nova Zembla, has been published by M. von Baer of St. Petersburgh, to whom I am indebted for a copy of his papers†. Some of his results we will immediately mention. 5. Dr. Richardson has undertaken the most laborious but most useful task of reducing into order, and into their mean results, the extensive series of two-hourly observations made in various years in the arctic regions of America by the expeditions of Parry and Franklin‡. This has also been partially done by M. von Baer, in the memoirs last-cited, so that we have in some measure a more complete meteorological knowledge of the climate of these desolate regions than we can be said to possess of that of our own country. Dr. Richardson has carefully compared his diurnal curves with those of Leith and Plymouth, and we find the constancy of the interval between the hours of mean temperature§ here remarkably reproduced, and also in a remarkable manner, Brewster's law of the correspondence of the mean temperature of two hours of the same name for the whole year with the mean temperature of the year‖. The latter fact comes out exceedingly well also from the tropical observations of M. Freycinet¶, and from the table of Brandes already referred to**.

38. All these observations go a long way towards the illustration of those general laws of climate which may be considered in some measure independent of local causes. It is not easy perhaps to conceive a more violent contrast of climate than the continental one of arctic America, and the insular one of Plymouth. It were undoubtedly to be desired, however, that these observations were extended to tropical regions; and the expeditions recently fitted out to St. Helena, the Cape of Good

* British Association, Fifth Report, p. 181; Eighth Report, p. 26.

† *Ueber das Clima von Nowaja-Semlja und die Mittlere Temperatur insbesondere; Ueber den Jährlichen Gang der Temperatur in Nowaja-Semlja.* Von K. E. v. Baer.—*Bulletin de l'Acad. Imp. de St. Pétersbourg*, t. ii. No. 19.

‡ Journal of the Royal Geographical Society, 1839.

§ See First Report, p. 211.

‖ Richardson, p. 39. From a communication made by Mr. Harris at Birmingham in 1839, it appears that hourly observations have been made at Philadelphia (United States) and in Ceylon; but the results are not published.

¶ Poisson, *Théorie de la Chaleur*, p. 465.

** To these may now be added two sets of hourly observations in Inverness-shire, made at the expense of the British Association under the direction of Sir D. Brewster. From the communication made by that gentleman to the Meeting of the Association in 1840, since this report was written, it appears, that in these observations also, the constancy of the interval between the hours of mean temperature mentioned in the text, is well preserved.

Hope, and the possessions of the East India Company, will doubtless ere long afford this information*.

39. The interesting tables of Von Baer and Richardson illustrate most remarkably the different progress of solar heat in arctic and temperate latitudes. The maximum *daily* range which occurs in the end of July at Padua, and exceeds 9° cent., occurs in March in Boothia (North America), and at Felsen Bay (Nova Zembla), in April†, the values being about 7° cent. At Leith the range is nearly uniform from April to July, and does not reach 6° cent., a proof of a temperate or insular climate. When the sun is always below the horizon, the diurnal curve is, as may be supposed, very uncertain, and wavering. In winter in Nova Zembla there is a sensible increase of temperature towards midnight, at both stations‡; and something of the same kind is visible in several of Dr. Richardson's winter curves.

40. The dependence of the form of the *annual* curve upon the insular or continental character of a locality, does not need here to be insisted on. But it is interesting to observe the contrast between the climates of arctic Asia and arctic America, both so rigorous, yet so unlike:—

The mean temp. of Nova Zembla is	16° F.	Of Fort Franklin	17·6
Mean temp. three summer months	36·5	,,	50·4
,, three winter months	—3	,,	—17·8

Nova Zembla, therefore, is a climate of wretched mediocrity; one of the most dreary in the known world; the summer temperature scarcely rises above the freezing point! whilst arctic America enjoys a European warmth for at least some weeks. The warmest month at Nova Zembla (August) has a temperature (39° F.) less than that of January in Shetland. The warmest month at Fort Franklin reaches 52°, or almost that of July in Shetland. The extremes are not less surprisingly different:—

Extreme heat at Nova Zembla	49° F.	At Fort Franklin	80° F.
,, cold ,,	—53§	,,	—58§
Range	102		138

* Since this report was written, I had the satisfaction of seeing, at the Tenth Meeting of the British Association, the admirable observations of Mr. Caldecott, at Trevandrum, in lat. 8° 30′ N., which it may be hoped will soon be published. They are on the thermometer, barometer, and hygrometer, made *hourly* for three years.

† The reason, of course, being, that as the sun approaches perpetual apparition, the daily variation diminishes. There is an approximation to this at Leith.

‡ Von Baer, *Täglicher Gang.*, p. 9.

§ The extreme of —53 appears to be a very uncommon one at Nova Zembla, much more so than —58 in North America. Captain Back observed so great a cold as —70°.

Enormous as both these ranges are, we cannot but observe that the Asiatic extreme warmth does not approach within 30° of the American one! and yet the mean temperature of both stations is nearly alike.

41. The determination of the diurnal curve of temperature and its variations may be almost called complete, in comparison with that of the annual curve, which, notwithstanding, is a matter in some respects of still more important concern. Even the mean temperature of a place, at any period, is very difficult to fix, owing to the great discrepancies of successive seasons. Thus 29 years, from 1806 to 1834, during which comparable observations have been statedly made at the Observatory at Paris, give a mean of 10°·822 cent., with a variation between one year and another from 12°·10c. in 1822, to 9°·35 c. in 1829, the difference being almost 5° of Fahrenheit*. It is evident that many years must be required to fix even this comparatively simple datum; how much more to determine the form of the annual curve which, in every region, is doubtless characterized by peculiar inflections!

42. The study of the annual curve is very much retarded by the want of simple, permanent, and comparable meteorological observations. These, which require little expense and little time, pre-suppose, from the extent of years over which they must extend, a kind of co-operation to which too little attention has been directed. The Paris observations are perhaps the only ones to which we can look with any degree of confidence in this respect, even for the comparatively short period of thirty years. Professor Brandes, of Breslau, has, with praiseworthy industry, collected and reduced a vast number of observations, continued at various stations for eight, ten, or more years, and has compared them and projected the annual curves, which he obtains by finding the mean temperature of successive periods of five days†. The chief stations are Petersburg, Stockholm, Cuxhaven, Zwanenburg, London, Mannheim, Vienna, St. Gotthard, La Rochelle, and Rome. In these curves, imperfect as they are, are well shown the peculiarities of insular and continental climates, and those of plains and mountains. Some points of agreement may probably be found in all, for which sufficient reasons may be assigned; such as the more rapid increase of temperature than its decline, which applies equally to the diurnal curve. This is, I conceive, chiefly owing to two causes,

* Poisson, *Théorie de la Chaleur*, p. 463.

† *Beiträge zur Witterungskunde*, von H. W. Brandes. 8vo. 1820. Untersuchungen über den mittleren Gang der Wärme-Aenderungen durchs ganze Jahr.

which I will simply indicate: *first*, that by its nature the absorption of heat due to direct radiation from the sun must go on more rapidly than the dissipation of it by cooling; and *secondly*, that some influence may be attributed to the different distribution of vapour during the rise and decline of temperature.

43. Owing to these causes, thermometric curves, if they can be assimilated to symmetric geometrical curves at all, such as parabolas, must be regarded as having their axes *oblique* and not *vertical.* An erect parabola cannot even, generally speaking, be employed for finding the maximum with exactness on this account. But, in point of fact, no one parabola can represent all the parts of the thermometric curves which, in their *least* complicated forms, approach more nearly to the curve of sines.

44. From the tables of Brandes and others, we may infer the probability of discovering special inflections of the annual curve which characterize particular regions of the globe. The European curves point, for instance, with great distinctness to a *check* in the progressive rise of temperature, owing to the increasing power of the sun, which occurs almost invariably in the middle of February. This inflection of the annual curve, which in Europe always bends it towards horizontality, and sometimes produces *distinctly* a second minimum in March, is a circumstance which has attracted too little attention, and as an indication of other general inflections deserves notice. This circumstance has lately been insisted on by M. Erman, in a letter to M. Arago*, who ascribes it, I think, with unwarrantable boldness, to the *interception of the solar rays by the passage of the meteors of November between the earth and sun!* I believe that it can be very easily accounted for, as occurring in Europe (which is all we know at present), by the periodic easterly winds of spring, caused by an unequal effect of temperature which we shall presently notice, and which almost invariably set in for a time at that season, bringing masses of cold air, from the continental regions of Europe and Asia, to the western shores†.

* *Comptes Rendus* (Paris), x. 21. (1840.)

† Since these pages were written, I have received from Prof. Dove of Berlin his elaborate Memoir "on the non-periodic changes of the Distribution of Temperature on the Earth's Surface," in which he has collected the most complete series existing of authentic observations of monthly mean temperature for fifty-nine stations. One of his conclusions is remarkable, viz. that when a large portion of the earth's surface is taken into view, the apparent irregularities of particular seasons counteract one another, so as to give no countenance to the idea, that more heat falls on the earth generally one year than another.

C. *Isothermal Lines**.

45. We will despatch very quickly what is to be said on the very important subject of climatology, because no material step whatever has been made since the publication of the last report. A considerable number of detached observations, of various degrees of merit, on the mean annual and monthly temperatures of many points of the earth's surface, have no doubt been added, and a list of many of these monographs may be found in Dove's *Repertorium* †, and in the Transactions of the Meteorological Society. M. Kämtz has performed the useful labour of amassing all the trustworthy observations of mean temperature which he could discover, and presenting the monthly means, in the second volume of his Meteorology. The German translation by Mahlmann of my former report, embraces figures on different projections of the isothermal and isogeothermal lines. Both of these, especially the last, require still the greatest attention, even to give an approximation to truth; but we have not yet obtained the roughest sketch of the variations which these lines undergo with change of season; in other words, of the isocheimal and isotheral lines ‡; yet these are of the greatest practical importance. The distribution of animal and vegetable life materially depends on them; the boundary of some plants being determined by the minimum winter temperature, and the advantageous cultivation of most by the extreme heat of summer; the limits of the vine, maize, and olive depend on these circumstances; and the region of barley so exactly coincides with the isotheral line, that (according to Wahlenberg) barley ripens wherever the mean temperature of ninety consecutive days rises to 48° Fahr.

46. Professor Dove has not inaptly compared the annual variations of the form of the great system of isothermal lines to those which the Lemniscates formed in some biaxal crystals seen by polarized light undergo by changes of temperature§.

47. These variations (to which we would particularly direct the efforts of meteorologists) are the more important, because, as we have already seen in treating of the form of the annual curve, places may have the same mean temperature, and yet their climates may have no real resemblance whatsoever (as when we compare the climates of Nova Zembla and Fort Franklin in North America, and those of Unst in Shetland and Copenhagen); and these characters may depend in a good measure upon local circumstances. Those who argue about

* Last Report, p. 214, &c. Mahlmann, p. 45. † iii. 266.
‡ Last Report, p. 218. § *L'Institut*, No. 325.

the constancy or inconstancy of climates from ancient times to the present*, would do well to recollect that their criteria are almost all drawn either from *extreme* temperatures, or from the facts of botanical geography, neither of which give true indications of the *mean* annual temperature of a climate.

48. From various remote regions we continue to receive interesting reports of the mean temperature, which seem generally to be more carefully and consistently made than in stations of easier access. It is indeed surprising, in how few points of the civilized parts of Europe the mean temperature can be said to be known with any degree of exactness, to which the verification of thermometers is an indispensable preliminary. We may mention, as particularly interesting amongst observations in the most inhospitable regions of the globe, the observations at Nova Zembla†, Dr. Richardson's reduction of those of Parry and Franklin, the observations of Beechey, Ross, and Back, in their respective voyages, the last of whom observed the greatest natural cold yet registered‡; Kupffer and Brewster§ on the temperatures observed on the north-west coast of America, and Arago upon similar observations by Macloughlin‖. Mr. Webster has given a list of extreme winters observed in North America¶; and Dr. Daubeny some observations on the climate of that country**; Mr. Trevelyan has reprinted his paper on the Climate and Vegetation of Farve, with additions††.

49. We have already observed, that it appears, by a reference to the Paris Tables, that a long series of years of observation is required to obtain with certainty the mean temperature of a place‡‡. It is probable that the temperature of the ground is not liable to so great fluctuation, and therefore that kind of observation should be made wherever practicable. This does not, however, supersede the necessity of long-continued meteorological observations with verified instruments made under proper precautions; and we hope to see the Plymouth observations, and those conducted at the various magnetic stations fixed upon by

* See on this interesting subject Arago, *Annuaire*, 1834; Schouw on the Climate of Italy (Ed. Phil. Journal, July 1840), and an anonymous paper in the Phil. Mag., Aug. 1840.

† Supra Art., 37—40.

‡ Ibid.

§ Phil. Mag., 3rd Series, i. 427.

‖ *Comptes Rendus* (Paris), i. 266.

¶ Silliman's Journal, xxviii. 183. The valuable Meteorological Reports from the State of New York are still continued, and, through the kindness of Dr. Romeyn Beck, I have received them down to 1837.

** Brit. Assoc., Eighth Rep., Sect. p. 29.

†† 4to. Florence, 1837.

‡‡ The longest extant series of meteorological observations worthy of any confidence is probably that at Berlin, printed in Dove's paper on Non-periodic Variations of Temperature (Berlin, 1840). It extends from 1719 to 1839; the greatest annual temperature was $9°{\cdot}69$ R. in 1756: the least $4°{\cdot}38$ R. in 1740.

the British government, continued for a series of years on this account. M. Boussingault has remarked, that at the Equator the mean temperature of any place may be found at any time of the year, and at any hour of the day, by digging a pit in a shady spot a foot deep, and observing the temperature at the bottom of it*. M. Poisson considers this result as conformable to theory†. It is, at all events, a most convenient fact, and adds one to the many encouragements which nature affords to the prosecution of meteorology in tropical regions, where hitherto it has been most neglected.

50. The improvement of our knowledge of terrestrial temperature is a most important branch of science. It may be doubted whether it has hitherto been cultivated in the right way, and whether local and minor anomalies have not been allowed to conceal the general laws which we should first seek to attain. It is quite certain, that the causes producing the inflexions of the isothermal lines are of the most irregular and unmathematical character, such as the boundaries of coasts and the like. Still we think that the time may not be far distant when we shall have isothermal charts as superior to those now existing, as Gauss's magnetic charts, deduced by skilful artifices from a limited number of good observations, are to those of Halley in the last century.

D. *Decrease of Temperature with Height*‡.

51. Part of what properly belongs to this head will be more conveniently treated of in considering the general question of the temperature of the globe and its appendages.

52. There is little doubt that the decrement of temperature is not uniform, but slower as we ascend. It is to this, probably, that we are to ascribe the greater values of the height due to 1° of decrement in equatorial than in temperate climates: thus, Boussingault found 26° c. of decrement for 4800 metres of ascent in the tropics, or . . . 1° c. for 184 met.

Col. Sykes, in India, on a height of 8500 ft., finds 1° F. for 332 ft. of ascent§, or	1° c. ,,	182 ,,
Whilst Saussure's mean value in the Alps is	1° c. ,,	154 ,,
Eschmann on the Rigi . . .	1° c. ,,	151 ,,

* *Ann. de Chim.* liii. *Annuaire*, 1836, p. 263.

† *Théorie de la Chaleur*, p. 508, &c.

‡ See First Report, p. 218, and Mahlmann, p. 53.

§ British Association, Fourth Report, p. 568.

M. Boblaye in Greece . . .	1° c.	for	150 met.
38 observations collected by Ramond	1° c.	„	164·7 „
And for Gay Lussac's aërostat alone	1° c.	„	184 „

as we might expect, from its great elevation*.

53. We have reason to believe, that in high latitudes the decrement is less rapid than in low ones; and M. Arago† has called particular attention to cases in which an actual *inversion* of the usual law occurs in the latitude of Spitzbergen‡, and on Arthur's Seat, near Edinburgh, during extreme cold§.

54. The decrement of temperature in the atmosphere, with reference to its constitution, has been considered in a lengthened series of papers, of which we cannot attempt an analysis, by M. Biot, lately published in the *Comptes Rendus de l'Académie des Sciences de Paris*, and in the *Connaissance des Tems*.

55. It has been considered in a more restricted point of view by Prof. Challis||, who has deduced from the properties of air, with regard to specific heat, a fall of 1° Fahr. for 186 feet, which is about a half too rapid. Mr. Lubbock, on the other hand, proceeding *à posteriori* from Gay Lussac's aërostat, has generalized the connexion of temperature and pressure so as to find the height of the atmosphere¶.

56. Any attempt, however, to connect the temperature and density of the atmosphere by laws such as regulate a laboratory experiment, must fail, in consequence of the incompleteness of the data. The increased specific heat of rarefied air is by no means the only cause of the diminished temperature of the higher regions of the atmosphere**. The higher the stratum, the more transcalent the medium which separates it from the planetary spaces, and therefore the freer will be the radiation in

* To convert *metres for* 1° *cent.* into *English feet for* 1° *Fahr.*, use the constant factor 1·8227 [log. 0·26072].

† *Comptes Rendus*, vii. 206.

‡ Observed by Captains Sabine and Foster.

§ Observed by Dr. Lind, 31 Jan. 1776. Phil. Trans. 1777.

|| Cambridge Transactions, vol. vi.

¶ On the Heat of Vapours, p. 21. Lond. 1840.

** On the specific Heat of Gases, see Dr. Apjohn's experiment by the use of the moist bulb hygrometer, (Brit. Assoc., Sixth Rep., Sect. Proceedings, p. 33,) and Suerman's Thesis, *De Calore fluidorum elasticorum specifico*, 4to. Trag. 1836, for which I was indebted to the ever-ready kindness of our late associate Dr. Moll. In these essays we find a new proof of the inexhaustible ingenuity by which philosophers have endeavoured to make amends for the practical difficulties of the direct problem: it is curious to see one and the same question treated, now by the aid of the calorimeter, now by observing the tone of an organ-pipe, and now by a dew-point experiment! Unfortunately, we cannot add that these various methods give the desired concordance of result. Regnault's are the latest experiments on the specific heat of simple bodies. *Ann. de Chim.* lxxiii. 1. (1840.)

that direction. Besides, the atmosphere is no doubt a medium of that description, which permits solar radiation to pass much more freely than heat which has combined with the materials of the globe at a low temperature; hence the surface of the globe may be considered as a true accumulating source of heat, the further we recede from which the greater will be the cold*.

57. A just apprehension of these circumstances will serve to explain the modifications of this phænomenon, as well as the phænomenon itself. This I have lately endeavoured to do, and to show the accordance of the theory with facts†. It is known, from experiment, that the decrement of temperature is most rapid in spring, and least so in autumn. This appears, both from the reduced observations on the Pentland Hills, near Edinburgh, alluded to in my last Report (p. 219), and from those on a great scale, conducted so long at Geneva and the Great St. Bernard‡. I have shown that this arises from the following peculiarities of the annual curves at two stations at different elevations; (1.) the curve at the upper or colder station stands wholly *below* that at the warmer one. Hence were these two curves *similar*, and their *epochs* the same, the difference would be constant. But (2.) the *range* at the upper station is less than that at the lower one; hence the summer difference of temperatures is on the whole *greater* than the winter difference, which we know to be the fact§. (3.) The maxima above occur later than those below, so that the whole colder and flatter curve is shifted to the *right* hand, and hence the epoch of maximum difference *precedes* the epoch of maximum temperature, according to a law which I have investigated in the paper referred to.

58. The diurnal curves correspond to the annual curves in the two first particulars, but not in the last. I have attempted to explain the cause of this difference, and to show that, in point of fact, the epoch of the diurnal curve at the higher station is (up to a certain height at least) *accelerated* upon the lower one instead of the reverse, and that consequently a *retardation* of the maximum *difference* upon the maximum temperature occurs, which is really the case‖. A clear apprehension of the progress of temperature in the atmosphere and

* See on this subject Fourier, *Mém. de l'Académie des Sciences*, tom. vii.; *Ann. de Chim.* xxvii. 155; Saussure, *Voyages dans les Alpes*, 4to, tom. ii. § 932, &c.; Kämtz, *Lehrbuch*, ii. 128; Pouillet, *Comptes Rendus*, vii. 49.

† Edinburgh Transactions, xiv. 489 (1840); and Jameson's Journal, October 1840.

‡ Dove's *Repertorium*, iii. 337.

§ See First Report, p. 219. Kämtz, *Lehrbuch*, ii. 140.

‖ Saussure, *Voyages*, iv. § 2050. Kämtz in *Poggendorff*, xxvii. 345.

earth leads to many interesting and important practical conclusions, upon which we cannot now dwell.

59. Whilst we admit the phænomenon of the decrease of temperature with height to be the normal one, and other cases exceptions, we must not omit to mention an important class of real exceptions, which deserve particular study.

60. The superior radiating power of Earth to Air is the cause of the seemingly preternatural depression of the temperature of the ground in clear evenings observed by Six, Wilson, and Pictet, and so well applied by Wells to the theory of dew. It is evident, that under the circumstances which favour the development of the cause (viz. Radiation), the effect must extend more or less above the surface; and, consequently, up to a certain point the temperature will *increase* with height. This question has lately been treated of in an interesting paper by Prof. Marcet*, who has arrived at the following conclusions:—1. It is a constant phænomenon about the time of sunset, except in the case of violent winds. 2. It attains a maximum immediately after sunset. 3. The increase of temperature with height extends to 100 or 110 feet at the most. 4. It is most conspicuous when the ground is covered with snow.

61. This leads us directly to the important subject of

E. *Radiation*†,

whether solar or terrestrial; in its bearings, perhaps, the most important and interesting at present connected with Meteorology. We speak now principally of instruments and primary results; in the next section, of conclusions to be drawn from them in connexion with great cosmical questions.

62. The earth acts by *absorbing* radiant heat from the sun and (perhaps) other heavenly bodies; and it *radiates* it again according to new laws towards space. Each of these effects, and the modifications which circumstances introduce into them, may be made the subject of separate experiment.

63. Since a thermometer with a blackened ball absorbs more solar heat than a bright or transparent one, it was natural to suppose that the difference of indication of two such instruments might be considered as a measure (at least a relative indication of the force) of solar radiation. The stationary dif-

* *Mémoires de la Société de Physique*, &c. *de Génève*, tom. viii. (1838).

† See First Report, p. 222; Mahlmann, p. 64. I think it unnecessary to say anything of the progress of our knowledge of Primary Physical Laws of Radiation, because that is to be made the subject of a special report by Professor Powell.

ference of such instruments was therefore observed by Lambert*, Leslie†, and others.

64. It is plain, however, that this indication can only be considered to be comparable with itself so long as all external circumstances *besides* solar radiation remain the same. This Saussure well showed by one of his admirable experiments‡, in which, by properly defending the thermometer from wind and common radiation, he raised its temperature in the sun to 190° Fahr. Sir John Herschel first pointed out that the *momentary* effect of the sun and other combined causes, in affecting the temperature of a thermometer, diminished by the *momentary* effect of those other causes acting separately, is the true relative measure of the force of the sun's rays. The first notice I have met with substantiating Sir John Herschel's claim to the application of this principle (which has since been rather unscrupulously adopted abroad with a slight change of form), is in a paper by the late Dr. Ritchie, in the Edinburgh Journal of Science for 1825 §, where he gives an extract from a letter of Sir John Herschel, who, in a few words, sufficiently describes the instrument and its principle. Full instructions for its use have lately been printed by the Royal Society ||; it is called an *actinometer*.

65. The *actinometer scale* is an arbitrary one, obtained by direct comparison of one instrument with another; and so satisfactory is this kind of observation, that, from direct experiment, I am satisfied that the value of the actinometric degrees may be obtained within $\frac{1}{100}$th of the amount of solar radiation. It is very singular, that Sir John Leslie, with his marked sagacity, should not have perceived that his mode of graduating photometers, by first converting them into hygrometers ¶, is radically erroneous; and accordingly I have found that, when his instruments are compared, after being constructed with the utmost care, they do not even approach to agreement except at 0°, unless they are of the same dimension, and in every respect similar; but absolute identity in size, material, and arrangement, it is beyond the power of art to obtain. Careful experiments, which I have likewise made with this elegant instrument under different skies and in different climates, compel me to conclude, that though in certain very uniform circumstances its relative indications may be really of value, yet in a wider

* *Pyrométrie*, p. 158. 4to. Berlin, 1779.

† Essay on Heat. Lond. 1804.

‡ *Voyages dans les Alpes*, § 932.

§ Vol. iii. p. 107.

|| Report of Committee of Physics, &c. 1840, p. 61.

¶ Essay on Heat, p. 421.

point of view they do not even afford the slightest approximation to the truth.

66. It does not, however, follow that the indications of the photometer are of no value, or that observations with it should be discontinued. There are some constant peculiarities in its action, so remarkable, as to suggest very interesting investigations. The effect of the reflected light of the sky is always *exceedingly* intense; so much so, as to give rise to the most paradoxical effects with regard to the *intensity* of solar radiation, if neglected. Thus I have found the whole effect of the sun and sky in a bright April day in this country, when many white clouds were present, not very inferior to that of the most piercing sunshine of the most sultry day of the south of Europe, unaccompanied by a single cloud. What would be the indications of the actinometer in these circumstances I am unable to state. M. Kämtz found, on the summit of the Faulhorn, that the direct solar effect on Leslie's photometer was equalled, and often exceeded, by that of the diffuse atmospheric influence*.

67. Sir John Herschel has lately proposed to render his scale an absolute one, denoting by an *actine* "the intensity of solar radiation, which, wholly absorbed at a vertical incidence, would suffice to melt a sheet of ice one-millionth of a metre in thickness in one minute†." With an actinometer, which marked 29°·5 as the maximum effect which he had observed in Europe, Sir John Herschel found the solar radiation at the Cape of Good Hope to attain 48°·75 of the same scale, the intensities being in the exact proportion of those numbers‡.

68. M. Pouillet, of Paris, described, some years ago, an apparatus for measuring solar radiation, in which the errors of other statical contrivances were in a good measure avoided, by enclosing the thermometer in an envelope maintained at 0° c., with the exception of a small hole, which exactly admitted the direct rays from the solar disc§. Since that time, however, he has adopted Herschel's dynamical method, which he has applied to a modification of the actinometer, which he terms a *pyrheliometer*; reserving (rather unfortunately I think) the term actinometer, which was already so fitly appropriated, to a separate apparatus for measuring nocturnal radiation. These instruments and their applications are described in an ingenious and interesting memoir read to the Academy of Sciences 9th July,

* *Lehrbuch*, iii. 14.
† Poggendorff, xli. 559. Royal Society's Report, p. 67.
‡ *Comptes Rendus* (Paris), iii. 506.
§ *Elémens de Physique*, 1832, tom. ii. p. 703, fig. 356.

1838, printed in the *Comptes Rendus**, and also privately circulated.

69. A question of very great importance in meteorology, and one of the first which radiation experiments were employed to determine, is the proportion of incident solar heat which is absorbed in its vertical passage through the atmosphere. In the acute, learned, and original work of Lambert on Photometry, published in 1760, (and now, I know not why, extremely scarce,) this question is fully discussed; formulæ are investigated for the total loss of light at any altitude, according to an assumed law of density, (which had already been done by Bouguer †, who first suggested the method,) and from a comparison of intensities at two elevations, the total loss in the atmosphere by a vertical transit is ingeniously deduced ‡. From experiments made at Coire with blackened thermometers, Lambert deduced the loss of light or heat by a vertical transit through a clear atmosphere to be about $\frac{4}{10}$ths of that incident on the exterior boundary §. Bouguer had estimated the loss of light at only one half as much.

70. Laplace ‖ investigated the law of extinction of light in the atmosphere, and showed that it may be made to depend approximately on the measure of refraction at any angle, by a very simple formula. He employed Bouguer's constant for 0° of zenith distance.

71. Sir John Leslie made experiments on the principle of Bouguer and Lambert, with his photometer placed in a position which equalized as much as possible the cooling causes, and admitted the direct heat of the sun ¶. The results are contained in the article *Climate*, in the Encyclopædia Britannica, from which it appears that he estimates the loss of heat by absorption at $\frac{1}{4}$th of that vertically incident.

72. Professor Kämtz, who has done full justice to Leslie's ele-

* *Mémoire sur la Chaleur Solaire, sur les pouvoirs rayonnants et absorbants de l'Air Atmosphérique, et sur la Température de l'Espace.—Comptes Rendus*, vii. 24.

† *Traité d'Optique*, &c. 4to. 1760, p. 306. Bouguer restricted his method to a comparison of the intensity of lunar light at different elevations with wax candles.

‡ Lambert, *Photometria, sive de Mensura et gradibus Luminis, Colorum, et Umbræ*, p. 392, &c.

§ *Photometria*, p. 397. Compare *Pyrometria*, § 283.

‖ *Mécanique Céleste*, iv. 282.

¶ Sir John Leslie himself gives no account of the circumstances under which the observations were made, but I learn from his assistant, that the photometer was placed under the revolving dome of the Edinburgh Observatory, the slit being turned towards the sun, and that it was observed very frequently at different hours.

gant instrument*, and who has endeavoured to separate from its indications that part which is due to reflexion from the atmosphere, finds by it, that at the summit of the Faulhorn, nearly 9000 feet above the sea, 30 per cent. of the vertical rays are already lost. With Herschel's actinometer (calculating always observations at different elevations by Lambert's formula), he obtains only 26 per cent. of loss at the Faulhorn, or 32 per cent. at the level of the sea. This was in perfectly clear weather.

73. M. Pouillet, employing likewise Lambert's formulæ, and the modification of the actinometer already mentioned, finds, at different seasons of the year, an absorption varying from 21 to 28 per cent., at a vertical incidence at Paris.

74. Saussure seems first to have thought of comparing directly the intensity of solar heat at the top and bottom of a mountain, and he contrived a heliothermometer for that purpose; and by experiments on the Cramont, to the south of Mont Blanc, he actually proved the increased intensity of the solar rays as we ascend, notwithstanding the diminution of temperature; undoubtedly a very remarkable experiment for the period†.

75. In 1832, Sir John Herschel kindly pointed out this problem to my attention, and furnished me with two actinometers. I had the rare good fortune to obtain the aid of Prof. Kämtz in making directly comparative experiments at the top and bottom of a column of air 6500 feet high, of known density, temperature, and humidity, under the most unexceptionable circumstances in point of weather. A provisional reduction of these experiments has given me 29 per cent. for the vertical loss at the level of the sea, a near agreement with the 32 per cent. independently determined by the method of Bouguer and Lambert with the same instrument at the same time.

76. Collecting these various results, we have for the *absorption of incident solar heat traversing the atmosphere vertically in clear weather*, the following fractions (incident heat = 1):—

Bouguer	·19
Lambert	·41
Leslie	·25
Kämtz	·32
Pouillet‡	·25
Kämtz and Forbes	·29
Mean	·285
Mean, omitting the two first .	·277

* *Lehrbuch*, iii. 10, &c. † Saussure, *Voyages*, 4to. iii. 310, and *note*.

‡ It appears from the remark of M. Pouillet, p. 8 of his Memoir, that he would make the fraction even lower for a perfectly pure sky.

77. Another method of measuring, or at least comparing the intensity of solar radiation, would be by the use of photographic paper*.

78. The next problem which radiation experiments may be expected to solve, is the quantity of heat *actually* received from the sun in a year on the surface of the earth. According to Pouillet's *last* estimate, this amounts to a quantity of heat capable of melting 31 metres' thickness of ice all over the globe†. Such estimates must be received with considerable diffidence.

79. The excess of heat received during the day is given off at night, or rather there is a perpetual radiation of heat from the globe towards the celestial spaces, which, granting the constancy of climate from age to age, must exactly equal the quantity of heat received. Observations of this kind may be made in various ways. The simplest is by exposing a thermometer to the aspect of the open sky, laying it on some freely radiating substance, such as snow, wool, or swandown. In this manner were conducted the experiments of Six, Wilson, and Wells. Wells noticed a difference of two thermometers, one in air, the other placed on swandown, amounting to 8·3 centigrade degrees‡ (15° F.). Boussingault, in his observations amidst the Andes, has recorded a depression of 6°·1; but the radiating thermometer was laid simply on turf, the other was suspended in the air at a height of 1·6 met. (5 ft. 4 in.)§. His observations were carried to a height of 4600 metres, where we should expect the effect of nocturnal radiation to be greatly increased, owing to the excessive transparency of the atmosphere. The same author mentions the curious fact, that to defend their crops from the intensity of the nocturnal cold, the natives of South America often make artificial clouds by means of smoke.

80. Leslie applied his differential thermometer to the measure of radiation by exposing one ball in the focus of a parabolic mirror, which he then called an ethrioscope. The conduct of systematic experiments of this kind is a matter of considerable difficulty. The only continuous series with which I am acquainted were made at Geneva during several years succeeding 1836, and published amongst the regular and excellent observations preserved in the *Bibliothèque Universelle*, a journal in

* See Herschel, Phil. Trans. 1840, p. 46. "Description of an Actinograph or self-registering Photometer for Meteorological purposes."

† *Mémoire sur la Chaleur Solaire*, p. 9. His former estimate was 14 metres only (see First Report, p. 222).

‡ Arago, *Annuaire*, 1836, p. 261. See also *Annuaire*, 1833, p. 214, &c.

§ *Ann. de Chim.* lii. 260.

which, during its long existence, marked attention has been given to the science of meteorology*. It does not appear, from the writings of Sir John Leslie himself, that he had ever obtained any very definite results by the use of the ethrioscope†. The action of the reflecting mirror seems not to be fully understood, at least so M. Pouillet asserts‡. I am unable, from experience, to verify his statement, which leaves, however, some ambiguity. M. Pouillet employs a vessel stuffed with swanskin (*peau de cygne*), capable of having its orifice directed at pleasure, and having a radiating thermometer in its centre. By ascertaining the effect upon this apparatus of a surface artificially maintained at a given temperature, he deduces the mean radiating temperature of the atmosphere considered as an indefinite concave. But this brings us to general questions of great interest and importance.

F. *Proper Temperature of the Globe and of Space*§.

81. I forbear to repeat what I have formerly said respecting the proofs of the proper temperature of the interior of the earth. I confine myself to a statement of the very important advances since made, both in experimental researches and in the induction of laws.

82. A few fundamental experiments are sufficient to maintain Fourier's position, that the interior heat of the earth exercises no perceptible influence on its present climate; we are therefore left to consider the effects of heating and cooling influences wholly external.

83. The imperfect transparency of the atmosphere stops a not inconsiderable share of the solar rays, which are therefore expended in heating it directly. But the major part reach the surface, and their effect being there concentrated (whilst in their transit through the atmosphere it is spread over a vast mass of air), the effect is incomparably more intense than elsewhere. The bounding surface of the earth (or ocean) and air is therefore to be considered as a true source of heat. From thence it is distributed *progressively* downwards by CONDUCTION‖, upwards by RADIATION and CONVECTION. The warmth

* *Bib. Univ.*, N. S., iii. 209, and subsequent volumes. Since the publication of the former report, we have to regret the loss of the late amiable Mr. George Maurice, principal editor of that journal.

† Articles CLIMATE and METEOROLOGY, *Encyclopædia Britannica*, New Edit.

‡ *Mém. Chal. Sol.*, p. 32.

§ First Report, p. 221; Mahlmann, p. 67, &c.

‖ Even in water. See the interesting and conclusive experiments by M. Despretz, *Comptes Rendus*, vii. 933.

of summer and the winter's cold are *gradually* propagated both upwards and downwards; and, in either case, with a diminishing intensity according to known laws. The annual curve of temperature in the ground is rapidly *retarded* and *flattened*, until, at a moderate depth, (60 to 100 feet, depending upon the conducting power and specific heat of the soil,) it sensibly coincides with a straight line, or the influence of seasons disappears; and the same takes place in the atmosphere at a great and unknown elevation.

84. The general principles of the communication of heat have led to the conclusions, 1. that the annual range should diminish geometrically as the depths below the surface increase arithmetically; 2. that the retardation of epochs increases uniformly with the depth*.

85. Both these conclusions of theory have been very satisfactorily verified by the experiments mentioned in the former report†, and extended since. And what is still more important, the verification of these two simple laws includes the introduction of certain constants, which may thus be determined *à posteriori*, and the general solution of problems of terrestrial conduction obtained.

86. Instead of merely citing the formulæ in which the expressions of the *constants of our globe and system* are involved, and which are found to express approximately the thermometric conditions of the strata of our globe near enough to the surface to be directly influenced by climateric changes, we will endeavour to trace, very generally, the *kind* of process by which mathematicians have attempted to reduce to law these most complicated and involved series of causes. In doing so we have a twofold object, which seems peculiarly congenial to the nature of such reports as the present; first, to extricate from a chaos of symbols (which would deter most persons from even tracing the connection of the data assumed, with the results announced), such results as apply immediately to the physical investigation; and secondly, to consider how far the really fundamental conditions of the problem have, or have not, been sacrificed to render the mathematical investigation practicable at all.

* See the original works on Heat of Fourier (particularly *Mém. de l'Institut*, 1821-22, p. 163) and Poisson, the elementary work of Prof. Kelland, and the Report by Prof. Whewell, on the Mathematical Theory of Heat. British Association, Fifth Report.

† P. 221. The experiments on buried thermometers, near Edinburgh, were made in the grounds of Mr. Ferguson, of Raith, by his permission, but were suggested and directed by the late Sir John Leslie. See Whewell's Report, p. 30; see also article CLIMATE, *Encyclopædia Britannica*.

87. The work in which the rigorous comparison of theory with experience in this most intricate inquiry has been most insisted on, is that of M. Poisson, of whose mathematical attainments it would be equally unnecessary and unbecoming in me to speak; any criticisms I have to offer will therefore be confined to the second of the heads I have noticed above; and to his writings* I will chiefly confine my attention.

88. So far as the effect of SOLAR HEAT is concerned, the *à priori* solution of the problem of the temperature of any part of the earth's surface may be thus imagined:—(1.) The *whole* quantity of sunshine which falls on any part of the earth's surface in the course of a year is to be found, and also the law of its variation of force at different seasons. (2.) The part of this heat which becomes effective in heating the earth's crust is to be found by multiplying the amount by a constant depending upon the absorbent power of the surface. (3.) This quantity of heat thus reduced is propagated towards the interior, according to the laws of conduction, which again pre-suppose the knowledge of two constants proper to each soil, namely, the Conductivity and the Specific Heat.

89. (1.) The measure of the quantity of sunshine received by any place in a year, and its distribution at different seasons, has been a favourite problem with mathematicians†. In ultimate analysis, it depends of course on the astronomical elements which affect the progress of the seasons, viz. the obliquity of the ecliptic (γ), the latitude of the place (μ), the excentricity of the earth's orbit (a), and the longitude of the sun's perigee (ϖ)‡. But there are also elements quite as important as any of these; the imperfect transparency of the air and its varying thickness, owing to differences of obliquity of the transmitted rays, and the condition of opacity depending on the weather. Neither of these are insignificant, neither of them compensatory; both may be considered as functions of the hour-angle and fraction of the year, and the second is besides subjected to the most capricious changes. Yet of these elements theory has hitherto taken no account, and consequently the expression for the quantity of sunshine obtained, in terms of astronomical constants, with so much labour, we must hold to be nearly useless as a physical datum. It is vain to say, with M. Poisson§, "Les lois d'absorption de la chaleur solaire à travers l'atmosphere, les variations diurnes et annuelles sont également

* *Théorie Mathématique de la Chaleur*, 4to. Paris, 1835, chap. xii. *Supplément*, 4to, 1837, and *Comptes Rendus*, iv. 137.

† See a list in Kämtz, *Lehrbuch*, i. 60.

‡ In Poisson's *Notation*.

§ *Théorie*, p. 475.

inconnues, et l'on peut seulement *supposer qu'elles sont peu considérables.*" We know, on the contrary, that they are so considerable, that, estimating the loss of radiant heat by a *vertical* passage through the atmosphere (76.) at only twenty-five per cent., at an angle of elevation of 25° the force of the solar rays would be reduced to a half, and at 5° to *one-twentieth* part. We know, indeed, that the difference of the *direct* effect of a vertical and a horizontal sun is due to this cause alone, exaggerated, of course, immensely by the variable meteorological state of the atmosphere, which again is a function of the latitude.

90. (2.) The receptive power of the surface is a datum which we find it very difficult directly to determine, and which, since the quantity of sunshine cannot (as we have seen) possibly be directly computed, must be inextricably mixed up with it. It might be a question, whether, by covering a tolerably extensive surface of soil, in which thermometers are inserted, with a composition of known superficial conductivity, this element might not become known.

91. (3.) The specific heat (c) and conductivity (k) of the soil are also inextricably mixed up together in the analysis; but either becoming known, the other may be inferred from thermometric observations carried below the surface. The specific heat seems that best adapted for laboratory experiments; M. Elie de Beaumont has assigned 0·5614 for the value of c (that for an equal *bulk* of water being = 1)*, proper to the soil at the Observatory of Paris.

92. To obtain the conductivity of the soil *à posteriori*, it is fortunately not necessary that the preceding theoretical estimation of the distribution of sunshine should be correct; but there are other estimates into which it essentially enters, and which must therefore be received with corresponding caution. To facilitate reference to M. Poisson's work, I will show how the simple and very satisfactory observation of maximum and minimum temperature of the earth's crust at given small depths (above the *invariable stratum*) may be made to yield a knowledge of some of the constants above referred to.

93. Let the excess of annual maximum above annual minimum temperature at a depth p be expressed by Δ_p; then

$$\log \Delta_p = A + B\,p\,\dagger$$

in which A of course denotes the log. range when $p = 0$ or

* Poisson, *Supplément*, p. 4.

† M. Quetelet puts under this form M. Poisson's equation.—See the memoir referred to below.

at the surface, and B determines the common ratio of the geometrical progression according to which the range diminishes. From observations with two thermometers at different depths, A and B may be obtained *à posteriori*.

94. Now when we consult M. Poisson's work, we find that his equation (23.), page 497, which is equivalent to the preceding one, is thus composed. The quantity A, on which the superficial range depends, contains (1) astronomical constants of climate γ, μ, α, ϖ already mentioned; (2) a temperature h depending on the mean force of the solar rays which have traversed the atmosphere and entered into combination with the earth's surface by absorption at a given place*; (3) the constant of conductivity k, and of specific heat c.

95. The co-efficient B, on which the *rate* of diminution of the range depends, is fortunately a very simple quantity, involving neither astronomical constants, nor those proper to the superficies. It is, in fact, an absolute number multiplied by $\sqrt{\frac{c}{k}}$, and from a knowledge of it (by observations with two or more thermometers) this quantity may be very readily and accurately determined; and it affords the only unexceptionable manner of ascertaining the conductivity of the earth's crust on a large scale. Observations to this effect have, from time to time, been made by thermometers plunged more or less below the soil; first, by Ott of Zurich, in 1762†; secondly, by Leslie near Edinburgh; thirdly, by Herrenschneider at Strasbourg‡; fourthly, by Muncke at Heidelberg§; fifthly, by Rudberg at Upsala; sixthly, by Arago at Paris; seventhly, by Quetelet at Brussels. An ad-

* Poisson, p. 480, where the definition of h is "Une température constante proportionelle à l'intensité de la chaleur solaire, telle qu'elle est à la distance moyenne de la terre au soleil et après avoir traversée l'atmosphère pour arriver au point O." It must not, however, be forgotten, that it includes ε, a constant of superficial absorption, and therefore varies from one point to another. See Poisson, p. 500. The quantity h is one of the most troublesome clearly to apprehend, and the dispersion (and sometimes permutation) of symbols throughout so large a work contributes to the ambiguity. I will therefore add, that in the value of h, page 480, namely, $\frac{\varepsilon S}{(\lambda + \lambda_1) a^2}$, ε is a constant of absorption for a given soil, but which may vary with the incidence of the rays (p. 474); S is the product of an element of surface, and a quantity of heat in the condition in which the atmosphere has transmitted it (p. 475); λ and λ_1 denote the proper superficial radiating power of the point O under consideration, and the cooling effect due to the contact of air (p. 349). The product of h by Q (see Art. 105, *note*) measures the thermometric efficiency of the solar rays in raising the climateric temperature of the spot (p. 518).

† Lambert's *Pyrométrie*, p. 356. ‡ Imperfect; only one thermometer.

§ Gives only the epochs.

mirable abstract and analysis of all these observations has been made by the last-named indefatigable observer, in a special memoir on the subject*, which we could hardly abridge without transcribing, and will therefore state chiefly the results with respect to the quantities A and B mentioned above. The following are the principal results in a tabular form, it being understood that in most of these cases no correction has been applied for the temperature of the liquid in the stem of the thermometer and between the bulb and the surface of the ground.

Place.	Number of Thermometers.	Years Observed.	Extreme Depth.	Calculated Depth at which the Annual Range is reduced to 0°·01 cent.	Value of A. (Log. superficial Range.)	Value of B. $\sqrt{\frac{c}{k}} \times$ const.	Velocity of Propagation. Days for 1 foot.
			feet.	feet.			days.
Zurich	8	$4\frac{1}{2}$	6 (Fr.?)	71	1·217	− ·038	5·7
Edinburgh	4	2	8 (Eng.)	58	1·068	− ·052	7
Strasbourg	1	3	15 (Fr.?)	81	1·279	− ·040	
Upsala............	3	$\frac{1}{2}$	3 ——	62	1·292	− ·053	
Paris	4	4	25 (Fr.)	69	1·376	− ·049	6
Brussels	7	3†	24 ——	76	1·151	− ·041	6·7

96. The following observations have been made at Edinburgh, under my direction, at the expense of the British Association‡, which, as well as those at Brussels, are completely corrected for the temperature of the liquid in the stems :—

Edinburgh In Trap Tufa.	4	3	24 (Fr.)	55	1·141	− ·057	6·8
— Loose Sand.	4	3	—	66	1·192	− ·048	6·2
— Sandstone. .	4	3	—	96	1·080	− ·032	4·0

97. These latter observations show very clearly the effect of *soil* in determining the velocity of propagation of heat which mainly depends upon the value of B, from which too the conductivity for heat of three very different geological formations may be accurately determined, so soon as the specific heat shall be known.

98. Observations of the same kind with the preceding have

* *Mémoire sur les Variations Diurne et Annuelle de la Température*, &c., 4to, *Bruxelles*, 1837. (From the *Mémoires de l'Académie de Bruxelles*, tom. x.)

† These observations have now been continued for three additional years, and the partial results are contained in the *Bulletin de l'Acad. de Bruxelles*, and the *Annuaire de l'Observatoire*. Since this report was read, I have received M. Quetelet's Systematic Reduction of the Observations at Bruxelles for 1837, 1838 and 1839. The results agree extremely well with those of previous years, and establish the formula of Art. 93. with remarkable precision. *Mém. de l'Acad. de Bruxelles*, tom. xiii. 1840.

‡ See Eighth and Ninth Reports, and Athenæum for September 1839.

been instituted at Bonn by Prof. Bischoff*, and at Freiburg in Saxony by Prof. Reich†; but of these, so far as I am aware, only imperfect notices have yet appeared.

99. The epochal retardations for the annual curves at the depth of a few feet follow, generally speaking, a simple law, for they are propagated uniformly downwards with a velocity which is easily connected with the constants proper to the soil determined from the range at two given depths, as just explained‡. It must not be concluded, however, that the epochs of earth-temperature at the surface coincide with those of air-temperature in the adjoining stratum. The difference of epoch may be obtained in terms of the conductivity and superficial characters of the solid stratum§. But the complete expression for the epoch at any depth in terms of the dates of maximum and minimum at some other depth, and of the constants of conductivity and surface, derived from two observed ranges, is so complex, that so far as I know, no attempt has been made to verify M. Poisson's formulæ except in a single example by himself, taken from M. Arago's observations||.

100. It is a matter of some practical difficulty to find the precise period of maximum and minimum temperature from observations at or near the surface, on account of the accidental fluctuations which occur, especially near the time of minimum, and which, even at a depth of three feet, produce in this climate an uncertainty sometimes of a week or more.

101. I have already stated, in the preceding table, the results

* *Wärmelehre* von G. Bischoff, 8vo, 1837, pp. 100, 392, 507. The observations were not made with long-tubed thermometers having their scales above ground, but by sinking bottles of water in wooden tubes to a certain depth, drawing them up rapidly, and observing their temperature. The observations were carried to a depth of 36 feet.

† Bischoff, ibid, p. 512.

‡ Poisson, p. 432. If X be the range at a depth x, and X' at depth x', and λ the retardation of epoch due to the increased depth from x to x', the following relation holds,

$$X' = X e^{-m\lambda}$$

m being a constant and e the base of Napier's logarithms.

§ Ibid.

|| P. 502–3. The coincidence is not so remarkable as a cursory inspection would suggest; there are not four coincidences but only two—the *data* and *quæsita* being reversed. The coincidence, such as it is, perhaps *proves too much*; for M. Arago's observations are not corrected for the temperature of the stem ("afin de pouvoir faire usage des observations non corrigées que M. Arago m'a communiquées, je supposerai que ces corrections soient peu considérables," p. 500); it is certain, however, that for the larger thermometers, where the range is *least*, and the *correction greatest*, the epochs must be (perhaps most materially) affected. The scientific world anxiously looks for the extended and reduced observations of M. Arago.

of different observations on the *rate of progress* of heat into the soil, especially as depending on its geological character, a compact sonorous sandstone transmitting heat at the rate of one foot in four days, whilst in loose sand (the same ingredient) it required 6·2 days. The following tables illustrate the varying retardation and proportionate diminution of amplitude (or range) at different depths*.

Depth in French Feet.	Maximum.			Minimum.			Range.		
	Trap.	Sand.	Sandst.	Trap.	Sand.	Sandst.	Trap.	Sand.	Sandst.
3	Aug. 5	Aug. 2	Aug, 7	Mar. 6	Feb. 28	Feb. 23	9° ·67c	11°·03c	9° ·67c
6	Sept. 1	Aug. 25	Ag. 19	Mar. 20	Mar. 22	Mar. 3	6° ·12	8°·05	7° ·68
12	Oct. 15	Oct. 8	Sept. 14	Apr. 25	Apr. 22	Mar. 26	2° ·85	4°·03	5° ·01
24	Jan. 6	Dec. 31	Nov. 6	July 15	July 1	May 12	0° ·75	1°·00	2° ·20

102. What we have now stated respecting annual variations of temperature, is found to be true, *mutatis mutandis*, for diurnal ones. Theory shows that the depth at which periodic fluctuations sensibly vanish should be (*cæteris paribus*) as the square roots of their periods, and this is found to be nearly the case in point of fact; the diurnal oscillation being nearly as insensible at a depth of three or four feet, as the annual one is at nineteen (or $\sqrt{365}$) times the depth, or at 60 or 70 feet†. M. Quetelet has made a most extensive series of observations at small depths, and he finds the diurnal heat-tide to penetrate at the rate of 1 decimetre (4 inches) in 2·8 hours nearly, in the month of March‡.

103. We now hasten to state a few other conclusions which have been attempted to be drawn from the very important class of observations of which we have recently spoken. Did we possess, in the actinometer or any other instrument, the means of measuring the actual force of sunshine in any place at a given moment, insuperable difficulties would yet arise to the determination of the very important questions, "To what extent does the *direct* solar influence actually contribute to produce the climate we enjoy?" and "What would be the temperature of our globe without the sun?" It is difficult or impossible for us to take cognizance of the perpetually fluctuating amount of solar heat, and to sum up the discontinuous amount of it during the year, allowing for intervals of darkness, atmospheric

* These numbers are (excepting the epochs of minima, which are but two years) a mean of three years. The temperatures are centigrade.

† Quetelet, *ut supra*, p. 72. ‡ Ibid, p. 68.

opacity, and cloudy weather; and even could this be accomplished, we should yet want data for knowing what portion of the incident heat combines with the earth so as to affect the climate. M. Pouillet, we have seen, has estimated the total quantity of sunshine incident on our globe*, but this was irrespective of modifications of weather, and of the variable quantity of sunshine in different latitudes.

104. A practical *à posteriori* determination of this *most important* meteorological element of the total quantity of effective solar heat, affecting the thermometric mean of any climate, has been suggested by M. Poisson. It seems well established by observations in the Caves at Paris, and by observations on the temperature of the earth at Geneva, that the *mean* air-temperature and *mean* superficial earth-temperature agree at these places, though their extremes differ both in amount and epoch. If, then, we can by any means find the *total* effect of the solar rays on the superficial earth stratum, we may assume that to be the effect due to the direct action of the sun in raising the temperature of the place.

105. M. Poisson has accordingly attempted most ingeniously to connect the climateric effect of the solar rays with the indications of thermometers sunk to small depths in the ground. From the value of the superficial range (whose logarithm is A in the expression of art. 93.) one of its factors h may be discovered, entering into combination with known or determinable quantities, and this quantity h is†, for any given spot, a number proportional to the direct climateric effect of the sun's rays which may be deduced from it‡. Now let us admit the mathematical accuracy of this very intricate investigation, and the admissibility

* Art. 78. † See art. 94, note.

‡ The value of A of art. 93, 94, is the following (in Poisson's *Notation*, page 497):

$$\log \frac{2\,b\,h}{D} \left(\tfrac{1}{2}\,\pi \sin \mu \sin \gamma - 2\,\alpha\,Q\right),$$

where α, γ, μ are astronomical constants already mentioned.

h is the constant of art. 94. *note.*

b is a constant depending on the superficial character of the soil, and also on its conductivity.

D is a function of b, of the specific heat of the soil, and of the longitude of the earth's perihelion.

Q is a very complicated function of the astronomical constants which determine the length of the day, and is one of a series of definite integrals of which the succeeding terms are neglected.

By the combination of two observed values of $A + B\,p$ (art. 93.) b and B are eliminated; the above expression contains only h and known quantities (Poisson, p. 499); and the product h Q expresses (p. 518) the number of degrees by which the annual mean temperature of the given place is affected by direct solar radiation.

of the approximations of calculation*, still we find little reason to trust implicitly to the results, however ingeniously obtained. We have seen (69.) that the effective action of solar radiation cannot be expressed simply by the quantity of heat which would fall on a square foot of the earth's surface were the atmosphere removed; but the absorption is very great even in the clearest weather, and therefore (even admitting a uniform distribution of vapours over the whole year, so that their opacity need not be considered as a function of the time) the quantity of solar heat depends on the thickness of the atmosphere traversed, and is therefore a function both of the hour angle and of the fraction of a year. The integrals, therefore, expressing the discontinuous quantity of sunshine, are wholly unadapted to the physical conditions of the problem.

106. That h cannot thereby be rightly estimated, will appear from this consideration: viz. that the whole effect of sunshine can only be deduced from the annual range at a given depth (or at the surface) by the following reasoning. The winter-action of the sun may (it is assumed) be compared *à priori* with the summer-action of the sun, and the excess of the latter action determined; but the Effect due to this Excess being observed (viz. the annual range), the effect due to either of the constituent actions (summer or winter) may be found, which gives the whole climateric effect of the sun at any season, and hence its mean effect throughout the year†. Now in applying this principle, it is clear that unless the *à priori* estimate of the sun's relative radiation in summer and winter be made on correct principles, a knowledge of the difference of effect due to the change of the cause will not lead to a correct value of the cause. In point of fact, a neglect of the absorption due to obliquity (not to mention the enormous excess of cloudy weather in the winter half-year) will inevitably lead to an *under* estimate of the proportion which the summer radiation bears to the winter radiation, and (as the difference between these effects is the quantity known) the value

* So involved are these expressions, that the author himself has inadvertently made use of two identical values of one quantity, this same h, and quoted the coincidence as a proof of the accuracy of the formulæ and observations (p. 503–4). This he admits in the *Supplément*, page 72.

† This at least is my understanding of the principles of solving the problem. The problem which Fourier has proposed (*Mém. de l'Institut*, v. 167, &c.) is a much simpler and also a less important one, viz. to find the quantity of solar heat alternately absorbed and emitted by the earth's surface in the course of a year, which evidently does not include the *permanent* or mean heat derived from the sun, and which is subject to no annual change, but which would be dissipated were the sun extinguished.

of the constituent effects will also be *under estimated,* or the climateric effect of the sun will come out too small.

107. Such, indeed, is almost certainly the case. The climateric effect of the sun at Paris is estimated from the superficial range of temperature (deduced by Poisson from Arago's experiments) to be only 24° cent.*. The mean temperature of Paris being 11° cent., there remains for the temperature which would remain if the direct influence of the sun were removed, — 13° c. or + 9° Fahr., a result altogether improbable. Further, the thickness of a sheet of ice over the whole globe which would be melted by the entire annual action of the sun, would be, according to Poisson, seven or eight metres†, whilst Pouillet supposes it four times as great‡.

108. Fourier, in his remarkable Memoir on the Heat of the Globe§, had clearly shown that its superficial temperature depends on three causes, which may be kept wholly distinct. 1. Solar heat. 2. Temperature of space. 3. Internal heat. To these M. Poisson has added Atmospheric Heat, which, however, is merely that part of the solar heat absorbed by the atmosphere and communicated secondarily to the earth, independent of that received by direct radiation.

109. Since the Report of Prof. Whewell on the Mathematical Theory of Heat, to which we refer for what had been written on these subjects at that time, several new contributions to this interesting branch of science have been made, both theoretically and experimentally; I allude particularly to the publication of Poisson's Theory of Heat, and Pouillet's Memoir before-cited.

110. Poisson's Theory of ATMOSPHERIC HEAT has met with a very just criticism, in almost every part of which I entirely agree, at the hands of Prof. Auguste de la Rive, of Geneva. His objections are so ably and clearly stated, that so far as they anticipate my own, it may be sufficient briefly to state them, and refer to his article || for details. And first, as to the constitution of the atmosphere: Poisson¶, adopting the reasoning of Fourier**, admits that the temperature of any part of the atmosphere must be determined by the equality of the heat directly received from the sun and indirectly from the earth, with that radiated abroad

* Poisson, p. 518. † Poisson's *Supplément*, p. 7.

‡ *Mémoire sur la Chaleur Solaire*, p. 9. (See above, art. 78.)

§ *Mémoires de l'Institut*, vii. 569; and Whewell's Report in British Association, Fifth Report, p. 30.

|| *Bibliothèque Universelle*, Nov.—Dec., 1835.

¶ *Théorie*, p. 448, &c. ** *Mém. de l'Institut.* vii. 584, &c.

in space, and in the adjacent atmospheric strata. Proceeding, however, to the mechanical conditions of equilibrium*, he infers that the temperature of the exterior part of the atmosphere must be prodigiously low, in order that it may have a definite termination, which condition of non-elasticity he calls liquefaction†, a term, the impropriety of which will sufficiently appear from the observations of M. de la Rive cited below‡. It is quite certain that an elastic atmosphere may be considered as rigorously limited, even wholly irrespective of the diminution of elasticity due to cold, and this without necessarily inferring an assent to the molecular constitution, from which Dr. Wollaston deduced the limitation as a necessary inference§. Hence, any hypothesis of extreme cold required to produce mechanical equilibrium in the higher parts of the atmosphere is devoid of support. As to the actual extent of the finite atmosphere, this is a question on which experiments both direct and indirect leave us much in the dark; nor can the optical phænomena of twilight be cited with much confidence in such a case, the reflective power of rarefied air being a datum on which we want direct evidence||.

111. The effect of the atmosphere upon the temperature of the globe, as treated of by M. Poisson, is twofold; namely, *first*, the modification of solar heat, which after combination with the air both radiates, and communicates heat by contact, to the earth; if the sun were extinguished, this heat would also vanish, al-

* *Théorie*, p. 459.

† *Théorie*, p. 459, and *Supplément*, note D. p. 60; *Traité de Mécanique*, ii. 612.

‡ " Nous ne pouvons admettre que cet état du fluide soit analogue à l'état liquide, du moins si nous attachons au mot liquide le sens physique dans lequel on l'entend communément, et par lequel on désigne, par exemple, l'état auquel une basse température et une forte compression amènent la plupart des fluides élastiques. Si M. Poisson n'entend par liquide que cet état des fluides dans lequel la force élastique est disparu, ce n'est plus alors qu'une définition mathématique qui est bonne tant qu'on ne cherche pas à se representer l'état physique du fluide. Toutefois observons que ce n'est pas ainsi qu'on définit les liquides; parceque l'état liquide suppose non seulement l'absence de force élastique, mais de plus une attraction moléculaire plus ou moins grande entre les particules du fluide, attraction qu'il nous est impossible d'admettre ici."—*Bib. Univ.*, Nov. 1835.

§ Phil. Trans., 1822, p. 89. Abstracts, ii. 160. M. Biot appears to give the credit of this remark to M. Poisson; *Comptes Rendus*, vi. 395.

|| See on this subject M. Biot's Memoirs; *Comptes Rendus*, viii. 91; ix. 174; Lambert's Works; Lubbock on Heat and Vapours, 1840; also Poisson, *Supplément à la Théorie de la Chaleur*, note D, where the author investigates the equilibrium of the atmosphere under certain conditions, but ends with these words: "il ne s'agit dans cette note, que d'un simple exemple de calcul, et vraisemblablement, les hypothèses que nous avons faites pour le faciliter ne sont pas conformes à la nature."

though for convenience it is distinguished from the direct solar heat measured by an actinometer; *secondly*, the proper low temperature of the higher atmosphere which is communicated to the earth by radiation through the inferior strata. M. Poisson contents himself with supposing that these two causes neutralize one another, or that the latter rather preponderates*, for which he assigns, I think, no sufficient reason; on the contrary, from what we have just stated (110.) of the action of the atmosphere, which lets more heat enter than can directly escape, we conceive that the heating effect of the atmosphere is essentially positive.

112. M. Poisson having thus estimated the direct solar effect on the climate of Paris at 24° cent., and the atmospheric influence as nothing relatively to the existing temperature, assigns the temperature which remains, namely, 11°, the actual mean temperature of Paris, diminished by 24°, or $-13°$ ($=8{\cdot}6$ Fahr.) for the heat of space, or the temperature which our globe would take were the sun permanently extinguished.

113. This result must certainly be considered as a very startling and improbable one. That the temperature which our globe would take did the sun not heat at all should be actually higher than the mean temperature of many points of its surface exposed to the solar rays during a great part of the year, and nearly 80° of Fahr. above a degree of natural cold actually observed†, is a paradox to which M. Arago drew attention, and which M. Poisson we think did not succeed in rendering plausible‡. Fourier was distinctly of opinion that the temperature of space must be lower than the *mean* of any point of the earth's surface, though he admits that local causes might produce a temporary depression§. The only explanation, indeed, which it can admit of, is that to which M. de la Rive has shown that Poisson's reasoning necessarily leads, viz. that the atmosphere is *an independent source of heat* ‖ (or cold, which is the same thing), a conclusion nowhere distinctly admitted by the author. Now this conclusion surely will be very reluctantly adopted, seeing that, even supposing the direct solar influence could be successfully estimated, the remaining temperature must be derived from (what is called) the heat of space and the heat of the atmosphere. Experiments are, I apprehend, totally wanting which can se-

* "La partie (namely, of the heat not directly received from the sun by any part of the earth's surface) provenant de l'atmosphère ne nous est pas connue; nous pouvons seulement présumer qu'elle est négative."—*Théorie*, p. 520.

† Viz. $-70°$ Fahr., by Captain Back.

‡ *Comptes Rendus* (Paris), ii. 575.

§ *Mém. de l'Institut*, vii. 582.

‖ *Bib. Univ.*, Dec. 1835.

parate these two united effects; their relation and absolute intensities are therefore, we presume, yet unknown; nor can we understand how it is possible that the higher strata of the atmosphere can remain permanently colder than the strata beneath and the sky above them, without admitting a paradox of the same kind with a mechanical perpetual motion.

114. I am aware that M. Pouillet, in his memoir so often cited, has been led to the same conclusion with M. Poisson respecting the low temperature of the aerial coating of the globe, and has actually computed the depression of temperature which might exist in various hypothetical cases. Until, however, M. Pouillet can exhibit an experiment in which so paradoxical a result is actually attained, I am inclined to think that we must consider it as at variance with the fundamental laws of heat as at present received. M. Pouillet has made many ingenious experiments with his instrument designed to measure nocturnal radiation; and (since the cooling effect of the sky may always be assimilated to that of a hollow sphere having a determinate temperature) he has, I believe for the first time, endeavoured to translate into numerical language the indications of his instrument by actually exposing it to the radiating action of surfaces of low temperature, which would have the same effect, whatever be their distance, and that effect being known in thermometric degrees on his instrument, the *equivalent* temperature of the vault of heaven, or what he calls zenithal temperature, becomes known too. All this is very ingenious and clear, and such determinations of zenithal temperatures will certainly one day be of great value. But the difficulty is to separate this temperature into that due to the atmosphere, and that due to the temperature of space. As already stated, we are not satisfied that such a separation has been, or at present can be effected; and the great variations of the assigned temperatures of space strengthen this doubt; for whilst Fourier and Swanberg make it $-40°$ c.*, Valz, $-45°$†, Poisson makes it $13°$‡, and Pouillet between $-115°$ and $-175°$§.

115. Fourier was the first who distinctly introduced the idea of the proper temperature of space, as well as the first who endeavoured to assign to it a value. Our ideas about an absolute zero

* See last Report, p. 203, and Fourier, *Mém. de l'Institut*, vii. p. 598. The grounds on which Fourier's estimate is made, nowhere exactly appear; Herschel considers his published statements unsatisfactory (Geol. Trans. III. 297); yet it appears that M. Fourier himself was strongly persuaded of the truth of his estimate, which he thought was not erroneous to the amount of 8° or 10° cent. (Arago's *Eloge de Fourier*, p. 55.)

† Mahlmann, p. 14, *note*. ‡ *Théorie*, p. 520.

§ *Mémoire sur la Chaleur Solaire*, p. 38.

of temperature, far from getting clearer, are perhaps now more unfixed than ever; and what would be the result of a condition of which we can form no very definite physical conception (a body placed in an envelope deprived of heat), it is perhaps too bold to conjecture. But that the planetary spaces are not exactly in this condition, is not improbable. A body (be it a thermometer or a planet) placed in space may take a temperature, by contact, from a fluid by which it is surrounded, or by radiation from distant stars (being shaded from the sun); the latter, we understand to be the meaning usually assigned by philosophers to the term *Temperature of Space**. This influence may change from age to age, and be variable in different regions of the globe, depending on their exposure. M. Poisson supposes that the increase of temperature with depth in the earth indicates the effect of an at-one-period-more-intense stellar radiation, and consequently that it does not necessarily extend beneath a depth which the epoch of the oscillations of external influence would determine. This is no doubt perfectly unanswerable, as a matter of bare possibility; but it seems hardly worth maintaining an opinion which a million of years will scarcely show to be feasible or the reverse†.

116. We have formerly stated ‡, that Fourier had arrived at the conclusion that the flux of heat from the interior to the surface of the globe did not raise the temperature of the latter above $\frac{1}{30}$th of a centigrade degree§, or would melt annually a stratum of ice $\frac{1}{10}$th of an English inch in thickness; and in this estimate Poisson nearly coincides‖. The influence of internal heat is quite irrespective of any theory as to the state of the nucleus, and depends only on the rate of increase as we descend, a circumstance which M. de la Rive seems to have overlooked in urging his objections against Poisson's theory. We proceed to state some important additions which have been made to our knowledge of FACTS respecting the thermometric condition of the accessible part of the earth's crust.

* See an interesting notice by Sir J. F. W. Herschel, read to the Royal Astronomical Society, 10 Jan. 1840; *Athenæum*, Feb. 15; where, as well as in a paper in the third volume of the Geological Transactions, New Series, *on Astronomical Causes affecting Geological Theories*, are some important suggestions on these intricate subjects.

† On the subject of the thermometric state of the globe, see a popular article by M. Arago (*Annuaire*, 1834), and the *Eloge* of Fourier, by the same author. In the *Annales de Chimie*, a few years since, Libri has given some results as to the rate of cooling, and the contraction of the earth's crust, within historic times, chiefly with a view to the supposed explanation which it affords of certain geological phænomena.

‡ Last Report, p. 221. § *Mém. de l'Institut*, vii. 590.

‖ *Théorie*, &c., p. 424.

117. We have no reason to admit any sensible change in the mean temperature of the superficial part of the globe; at least we are rather disposed to attribute the manifest elevation of temperature observed during twenty years, in the observations in the caverns under the Observatory at Paris, to some permanent alteration in the instrument than to a change of temperature of the earth, a point which we hope the French astronomers will take pains to ascertain. The observations from 1817 to 1835 being divided into four series, give the following results:—

11°·730 11°·801 11°·857 11°·950*

118. The mean of 352 observations is 11·834; the mean temperature of the air at Paris is 10·822†; the difference is to be attributed to the increase of terrestrial heat for 28 metres of descent.

119. Observations on borings, and overflowing or Artesian wells, have been perhaps more unexceptionable of late years than at any former period. We shall give such indications as to record the chief facts observed. Amongst the best observations are those made by MM. De la Rive and Marcet in a boring near Geneva‡, under the most unexceptionable circumstances, which agree extremely well in indicating a *uniform* increase of heat at the rate of 1° cent. for 32·55 metres of descent, or 59 feet for 1° Fahr. The whole depth was 255 metres.

120. A list of Artesian wells and their temperatures has been given by M. Arago, in the *Annuaire* for 1835; and by Poisson, on the same authority, in his Theory of Heat§; whence he has deduced (from fifteen Artesian wells in France, all above 20 metres deep) an increase of 1° cent. for 25·46 metres of descent (46 feet for 1° Fahr.). There appears in these, as well as the Geneva and Paris observations, a remarkable coincidence between the superficial ground-temperature and the observed air-temperature‖.

121. From the comparison of a number of observations, M. Kupffer¶ deduces an increase of 25·37 metres for 1° *Reaumur*, or 20·30 m. for 1° cent., or 37 feet for 1° Fahr.

122. A well at Magdeburg gives 1° *Reaumur* for 100 feet, or 44 feet for 1° Fahr.**, according to Professor Magnus, the inventor of an improved thermometer for such observations.

* Poisson, *Théorie de la Chaleur*, p. 414. † Ibid, p. 467.

‡ *Mém. de la Soc. de Phys. de Génève*, tom. vi. § P. 420.

‖ It is by no means necessary to infer, however, that this is a *general* fact. Prof. Reich's observations, for example, at Freiberg, indicate an excess of 1° c. in the earth-temperature above the air-temperature. *Beob. über die Temp. des Gesteins*, &c., p. 134.

¶ Poggendorff, xxxii. 284. ** Ibid., xl. 139. See also xxxviii. 593.

123. A very deep experimental bore has been sunk at La Grenelle, near Paris. The latest report* (Aug. 1839) gives a temperature of 27°·5 cent. at a depth of 281 metres, which would infer an increase of about 1° cent. for $16\frac{1}{2}$ metres (the superficial temperature being under 11°), a result hardly probable†; and as the depth of the bore then was between 400 and 500 metres, either the depth of observation has been misstated, or the temperature was raised by water flowing from the bottom.

124. The following are the depths of the most remarkable Artesian wells at present known ‡:—

	French feet.
La Grenelle, Paris (June 1839)	1436·1
Neu Salzwerk, near Minden (Sept. 1839) . . .	1434·8
Temperature of brine, 18°·5 R.	
Nowe Brzesko, Poland (1838)	1403·8
Cessingen, Luxembourg (April 1839)	1646·5 §

125. Perhaps the most interesting, and certainly the most singular observations, on subterranean temperature, are those on the frozen soil of Siberia. At Jakouzk, in lat. 62°, where the mean temperature is −6° Reaum. = 18·5 Fahr. (accompanied with such a rigour of climate, that *mercury has been known to remain frozen for three consecutive months* ||), the heat of summer thaws the soil to an extreme depth of only three feet¶. To search for a permanent spring is a matter of great difficulty. A well has been dug to the depth of nearly 400 English feet, with the following most remarkable results as to the temperature of the ground** :—

Surface	− 6°· Reaumur.
77 English feet . . .	− 5 ·5
119 „	− 4 ·0
382 „	− 0 ·5

* *Comptes Rendus* (Paris), ix. 218.

† This result is altogether at variance with that formerly published (*Comptes Rendus*, vi. 505), where it appears that at a depth of 400 metres the temperature was 23°·5 c., giving an increase of 1° c. for 31·5 metres, in which also some other springs near Paris very nearly coincide. *A still later observation confirms this remark. On the* 18*th August*, 1840, *MM. Arago and Walferdin obtained a temperature of* 26°· 43 *c. at* 505 *metres, giving* 32·3 *metres for* 1° *c.* (*Comptes Rendus*, 2 Nov., 1840.)

‡ Poggendorff, xlviii. 382. Notices of some other Artesian wells, Pogg., xxix. 362. For an account of two Artesian brine springs at Kissengen, see my paper in Jameson's Journal, April 1839.

§ It has lately been stated, that the observations of temperature in this Artesian well, at the depths of 180, 230, 280, and 337 metres, give a coincident result of 1° c. for 13 metres of descent, or more than twice as rapid an increase as that usually observed. (*L'Institut*, 1840, No. 340.)

|| Erman, *Comptes Rendus* (Paris), vi. 502.

¶ Bischoff, *Wärmelehre*, p. 137.

** Erman, *ut sup.* See also Von Baer, in Brit. Assoc., Eighth Rep., Sect. p. 96.

From which it appears that we have a progressive increase of temperature in the frozen soil, which, at a depth of about 400 feet, will give a temperature just freezing. The augmentation would appear to be more rapid than usual, or 1° R. for 60 or 70 English feet.

126. Of observations in mines we have a most important and extensive series by Professor Reich, of Freiberg*, made under the most favourable circumstances, and with every assurance of their accuracy. They extend to a depth of above 900 feet, and the result of the combination of the whole is an increase of 1° cent. for 41·84 metres, or 1° Fahr. for 76 English feet, with a probable error of only 1-37th part†.

127. Professor Phillips found, in the Monkwearmouth coal-pit, an increase of 25° Fahr. for 1484 feet of descent, or 1° Fahr. for 59·36 English feet‡. The same gentleman has given valuable instructions for conducting such observations§.

128. Mr. Fox gives 1° Fahr. for 48 or 50 feet as the results of his experiments in Cornwall||. Mr. Henwood agrees with Mr. Fox in finding a difference in the progression of heat in slate (killas) and granite, and gives the following summary of his experiments¶:—

95 observations in slate		1° F.	for	39 feet.
39	„ granite	„		41·4

This difference, Mr. Fox thinks, is probably attributable to the action of the mechanical structure of the rocks, in admitting superficial water**.

* *Beobachtungen über die Temperatur des Gesteins in verschiedenen Tiefen in den Gruben des Sächsischen Erzgebirges in den Jahren* 1830 *bis* 1832, von F. Reich. 8vo. Freiberg, 1834.

† P. 131. ‡ Phil. Mag., Third Series, v. 451.

§ Brit. Assoc., Sixth Rep., p. 291. || Ibid., Seventh Rep., p. 136, &c.

¶ Ibid., Seventh Rep., Sections, p. 36.

** It will be seen that these experiments have no analogy in their objects with those made at Edinburgh on the influence of the material of the strata upon the admission of solar heat, as Dove seems to suppose (*Repertorium*, III. 307).

A most important question, connected with earth-temperature, yet remains to be decided. M. Kupffer maintains (see First Report, p. 224), that the superficial temperature of the earth exceeds that of the air in high latitudes, and falls short of it between the tropics (as was long ago asserted by Von Buch and others), and he has described Isogeothermal lines to express this fact. Bischoff maintains the contrary (*Wärmelehre*, p. 38, &c.), declaring that Kupffer's lines coincide with those of Humboldt (Isothermal), and that the warmth of springs in high latitudes arises solely from the *depth* at which they rise (p. 53), and he quotes the observations made by Boussingault, *one foot* below the surface (where he finds the temperature *constant* in tropical regions, and equal to the mean air-temperature of the year, *Ann. de Chimie*, liii. 225), in support of the assertion, that at the equator no difference of air- and earth-temperature exists.

129. Most intimately connected with the subject of subterranean temperature is that of the temperature of springs, which connects itself so remarkably with chemical, geological, and meteorological considerations. It is impossible not to adopt the idea, that the temperature of spring-water depends on the depth whence it takes its origin, since we now know, beyond any doubt, that up to a certain point at least, the heat of the strata increases as we descend; nor is there the slightest reason to suppose that this progression undergoes any considerable variation down to the (comparatively) moderate depth at which water would boil, however much we may feel the necessity of caution in inferring the actual condition of the earth's nucleus. The subject is one of so much extent, that we must refer generally to the works which specifically treat of it, amongst which that of Prof. Bischoff, of Bonn*, is the most important in our present point of view. According to him, the temperature of a spring is an index simply of the thermal condition of the stratum whence it takes its origin, or at least derives its chief heat.

130. A very ingenious application of these principles has been made by Prof. Kupffer, and he has illustrated them by an application to observations of the temperature of two springs at slightly different elevations, near Edinburgh, made at different seasons of the year†. By observing the annual range of temperature of the spring, its depth is known by Fourier's formula, the conductivity of the soil being assumed from Leslie's experiments. The retardation of epochs is also an index of the depth. Now the actual difference of level of the points of exit of the two springs being given, the difference of temperature due to height above the sea is known. The *actual*

Very contrary results on the latter point, derived from springs, appear in M. Arago's report on a recent French expedition, under command of Capt. Du-Petit-Thouars (*Annuaire*, 1840, p. 296), from which the ground would seem to be sometimes 4° cent. colder than the air.—*Nov.* 1840.

* *Die Wärmelehre des Innern unsers Erdkörpers*, 8vo. Leipzig, 1837. Some part of this work has been translated in the Edinburgh Philosophical Journal. It consists of four parts, containing 27 chapters, and is full of research and important information.

† These observations, published anonymously in Prof. Jameson's Journal in 1828, were made by me. I have only lately found that they have been subjected to an ingenious and searching analysis, first by Kämtz (*Météorologie*, ii. 190) afterwards by Kupffer (Poggendorff's *Annalen*, xxxii. 280), and made to yield results which, in making them, I could not have contemplated. This is one instance out of many, for the encouragement of young observers, showing that observations conducted on system, carefully and perseveringly made, and complete so far as they go, may afterwards prove of unexpected importance.

difference of observed temperatures is not, however, the same, because the one spring rose from a greater depth than the other. The variation due to this cause then becomes apparent; and the difference of depth from which they rise being known, the rate of increase is found by M. Kupffer to be 1° Fahr. for 41 English feet; a process which must be admitted, at all events, to be extremely ingenious. He has treated some of Wahlenberg's observations in a similar way*.

131. On the subject of hot-springs, or those which have a temperature notably higher than that of the air, (though, as Bischoff has well remarked, there is an insensible gradation,) we cannot now enter; and this is the less to be regretted, as Dr. Daubeny has already presented an ample report to the British Association on the subject†. M. Arago has published some valuable remarks on the same subject, especially on the curious phænomena of the springs of Aix in Provence‡. With a view to direct the attention of naturalists to the secular and annual changes of temperature in hot-springs, I have made some very detailed investigations on this subject, which I have published, as far as relates to those in the Pyrenees§. The central heat theory would require these to be insensible, as indeed they appear to be in the best known instances.

II.—Atmospheric Pressure.

A. *Barometers*||.

132. The standard barometer of the Royal Society of London has two tubes, one of flint, the other of crown glass, adapted to a common cistern, with a view, it is believed, of ascertaining whether any change in the capillary action occurs, depending on the nature of the tube. The scale, according to Dr. Prout's ingenious construction, is itself moveable, its zero coinciding with a fine agate point, which terminates it, and which may be brought into the nicest contact with the mercurial surface in

* In Prof. Kämtz's *Lehrbuch der Meteorologie*, ii. 186, &c., is much valuable information on the subject of springs; also in Dove's *Repertorium*, iii. 310.

† British Association, Sixth Report, pp. 1—95.

‡ *Annuaire du Bureau des Longitudes*, 1836, p. 265; see also M. Valz's communication, *Comptes Rendus*, vol. x.

§ Phil. Trans. 1836. On the subject of hot springs, Osaun's work in 2 vols. 8vo. (*Europa's Heilquellen*, Berlin, 1829), may be consulted in German, Alibert's in French, and Gairdner's in English; but the temperature observations seldom afford more than a rude approximation to the truth.

|| See last Report, p. 225. Mahlmann, p. 77.

the cistern; the vernier has a proper motion upon the scale, in order to read off the height*.

133. M. Kupffer has proposed a stationary barometer, in which a siphon-tube stands alone, and quite detached from a graduated column, along which a micrometer travels, and reads off the differences of elevation of the two extremities of the mercury†. M. Breithaupt has also proposed a plan somewhat similar‡. It may very safely be affirmed, that the mechanical act of reading off the length of the column is already accomplished with more accuracy than the otherwise imperfect nature of the instrument requires.

134. Mr. Daniell recommends Newman's portable barometers, with correction for the capacity of the cistern, and such have been supplied to the Antarctic expedition§. Mr. Newman has adapted an ingenious cast-iron cistern to his instrument, which consists of two parts, one of which contains the superfluous mercury during carriage, the other being always full‖.

135. M. Bunten, of Paris, a most ingenious and excellent artist, has made a great improvement on Gay-Lussac's portable siphon-barometer, in which a chamber is left in the principal tube, in which any air which may have accidentally left the bend of the siphon is inevitably lodged, and may be expelled at leisure without injury to the vacuum. M. Bunten constructs these instruments himself with peculiar skill, and provides them with excellent portable wooden cases. The same artist has recently contrived a very ingenious, elegant, and simple cistern-barometer, with the graduation on the glass, and which can be made at so moderate a price as ought to supersede the rude instruments commonly purchased at twice the cost¶.

136. Greiner, of Berlin, a most excellent manufacturer of meteorological instruments of the most delicate kind, has constructed a siphon-barometer, with the material advantage of *confining* the superfluous mercury (which by frequent shaking becomes oxidated), and yet in such a way, that the expansion by heat cannot possibly endanger the instrument**. His barometer, more cumbrous and more expensive than Bunten's, is well adapted for nice observations, to be pursued for some time at a fixed station, whither the instrument has first to be conveyed.

* See Mr. Baily's description, Phil. Mag., Third Series, xii. 204.

† Poggendorff, xxvi. 446.

‡ Ibid., xxxiv. 30.

§ Royal Society, Instructions, p. 56.

‖ Brit. Assoc., 3rd Report, p. 417.

¶ The defect of this instrument in its present form, is the difficulty of access of the air to the cistern.

** There is a descriptive pamphlet published at Berlin in 1835.

137. Mr. Harris, of Plymouth, has had the merit of executing, for the first time, perhaps, with accuracy, a wheel, or circular index-barometer, a matter of very great importance as well as difficulty, because it enables unlearned persons to read off the height without the aid of a vernier; and in fact to this we owe the most valuable and unique series of hourly barometrical observations, to which we shall presently refer*.

138. Prof. Stevelly, of Belfast, has proposed a self-registering barometer, on the principle of causing a moveable cistern containing mercury to rise or fall by the weight of the fluid displaced from a fixed barometer tube immersed in it. The tube here may evidently be opaque, as of iron†.

139. A water-barometer has been constructed and observed in the Royal Society's Apartments (London). Some elaborate comparisons of its indications with standard instruments will be found in Mr. Hudson's paper‡.

140. On the still-agitated subject of capillarity, as affecting barometric readings, I refer to some recent essays of Bessel, Dulong, and Bohnenberger§.

141. Of barometers acting on principles different from that of a simple column of mercury, the so-called (not very appropriately) differential barometer of Auguste, as improved by Kopp‖, is the most ingenious. Its principle, so far as it can be concisely stated without a figure, is this: if air of any density whatever be compressed into a given fraction, say $\frac{3}{4}$ths of its natural bulk, it will sustain a pressure equal to the atmospheric pressure, and a certain fraction more, depending on the fraction denoting the compression (in the supposed case its elasticity would be balanced by the atmospheric pressure, and $\frac{1}{3}$rd more). If, then, this fraction of excess of pressure is known by experiment, the whole pressure is inferred from a knowledge of the construction of the instrument. Thus, instead of a column of 30 inches of mercury being required, one of 15, 10, or any other number may be used and multiplied by the constant factor. In Kopp's instrument, the experiment is very simply and neatly made. A glass chamber communicates freely with a vertical tube, which is open to the air until mercury forced in from beneath cuts off the communication: the pressure by which the mercury is introduced being continued, the air in the chamber is condensed, and the mercury rises in the vertical tube, so that its pressure, together with that of the atmosphere, may balance the elasticity of the air. The compression is continued until the air is

* British Association, Third Report, p. 414.

† Transactions of the Royal Irish Academy, 1836.

‡ Phil. Trans. 1832.

§ Poggendorff, xxvi. 451.

‖ Poggendorff, xl. 62.

observed to be condensed to a known fraction of its bulk, when the length of the column of mercury is also a known fraction of the total barometric column. I brought one of these instruments to this country two years ago, but I have not yet made trial of it.

142. Mr. Cooper has proposed a barometer acting by the elasticity of the air in a floating vessel regulated by weights, which constantly immerse it to the same depth*. The author considers it capable of showing a difference of elevation of three or four feet. It is intended that the apparatus should in every case be employed at a constant temperature of 75°, to which it is artificially brought: I conceive that this process is attended with inevitable disadvantages.

143. Sir John Robison has proposed to use tubes or long phials containing air, immersed in water at the top of a hill, instead of an air barometer or sympiezometer. The portion which becomes filled with water, when re-examined, would indicate the previous rarefaction of the air†. In this and every similar case the temperature of the included air is a matter of great uncertainty, and prevents the possibility (as contemplated) of trusting such instruments to inexperienced assistants.

B. *Mean Height of the Barometer.*

144. Several considerations would lead us to the inference, that the mean pressure of the atmosphere at the level of the sea should vary with the latitude; but it is to experiment alone that we can look for any indication of a law. Humboldt appears first to have remarked, that the height of the barometer is lower at the equator than in temperate latitudes‡; and, excepting this fact, little more has been known until the late excellent researches of Schouw§, though the partial observations of occasional navigators indicate this fact, as well as a very considerable depression of the barometer towards the pole||.

145. M. Schouw's statement is the following:—

		Mean pressure at Level Sea, in French Lines.
Lat.	0° to 15° high temp. with a rainy season	337—7
,,	15 — 30 very dry; rains rarely . . .	338—9
,,	30 — 45 temperate	339—7·5
,,	45 — 65 cold and rainy	337·5—3

* Philosophical Transactions, 1839, p. 425.

† British Association, Eighth Report, Sections, p. 37. Brunner has described an air-barometer, Poggendorff, xxxiv. 30.

‡ *Tableau Physique*, p. 89, quoted by Kämtz.

§ *Annales de Chimie*, tome liii. (1833). See also Poggendorff, xxvi. 395.

|| See the authorities cited in Humboldt's Note to Arago, *Comptes Rendus*, ii. 570. Some valuable comparisons of barometers at different northern observatories are to be found in a late number of the *Comptes Rendus* (1840. 2me Semestre).

The maximum appears then to be about the 45th degree, and it diminishes on either hand.

146. The equatorial depression, and the maximum near the 40th degree of latitude, is indicated not only by the *fixed* annual observations given in Schouw's paper, but also by progressive observations made on board ship by Capt. Beechey*, Sir J. Herschel†, Sir E. Ryan†, and Mr. MacHardy†; the latter are important, as showing that the same distribution prevails in the southern hemisphere. Mr. MacHardy's observations in *southern* latitudes give

Between 0° and	5° S.	29·821 Eng. inches.
,, 5 ,,	15	29·802 ,,
,, 15 ,,	25	29·960 ,,
,, 25 ,,	35	30·085 ,,

147. Prof. Poggendorff, of Berlin, has very justly remarked‡, that the question of the actual pressure of the air at any point of the earth's surface, supposes that that pressure is measured upon a *constant scale of force;* but owing to the variation of the force of gravity, the weight of a given length of the mercurial column is not constant, and the effect of attending to this correction is to exaggerate the depression at the equator, and diminish somewhat (but not annihilate) that in the arctic regions. Such a corrected table, deduced from Schouw's, will be found in the *Comptes Rendus* and in Poggendorff's Journal. The propriety of the correction will be evident (as M. Poggendorff observes), if we recollect that the elasticity of air, and the boiling point of water, may be used, as well as the counterpoise of mercury, for indicating the atmospheric pressure.

148. The height of the barometer, at least in temperate regions, varies with the season of the year. At Paris and Strasburg it appears to attain one maximum in summer and another in winter. M. Kämtz attributes the summer maximum, with great probability, to the pressure of vapour§: when this is allowed for, we have a maximum in February and a minimum in August or September. The prevalence of particular winds (as we shall see) causes temporary elevations of the barometer in particular parts of the earth's surface, which may lead, and have led, to very erroneous conclusions.

149. There seems, however, on the whole, no reason to doubt the existence of such *atmospheric valleys* as were adverted to in the former report‖.

* *Comptes Rendus*, ii. 572.

† Second Report of the Meteorological Committee of the South African Institution, p. 2 (for which I am indebted to Sir J. Herschel).

‡ *Annalen der Physik*, xxxvii. 468.

§ *Lehrbuch*, ii. 297.

‖ P. 228.

150. There is no instrumental result to be received at all times with more doubt than the *absolute* height of the barometer. I have had occasion to compare many which have the character of being standard instruments, and have found the most serious inconsistencies. There are few points at which the mean pressure of the atmosphere can be said to be *accurately* known. Even at Paris there is some little doubt* ; when reduced to the level of the sea, it appears to be 760·85 millimetres†. From seventeen years of very careful observations at Marseilles, it is 761·61 at 0°, and at the level of the sea‡, clearly indicating that Paris lies considerably to the N. of the maximum pressure zone. It may be doubted whether we possess in this country any satisfactory evidence of the mean height of the barometer at the level of the sea§.

C. *Barometric Oscillations*‖.

151. The investigation, by Mr. Snow Harris, of the diurnal atmospheric tide by means of hourly observations, continued at Plymouth night and day for three years¶, has led to a very satisfactory determination both of the epoch and amount. According to him, the maxima occur at $9\frac{2}{3}^{h}$ A.M., and at 10^{h} P.M., the minima at $4\frac{1}{4}^{h}$ A.M., and $3\frac{1}{4}^{h}$ P.M.; and the measures appear to be the following (approximately):—

Rise from 4 A.M. to 10 A.M.	. .	·014 inch
Fall „ 10 A.M. to 3 P.M.	. .	·017 „
Rise „ 3 P.M. to 10 P.M.	. .	·021 „
Fall „ 10 P.M. to 4 A.M.	. .	·018 „

The maximum oscillation here appears to be between 3 P.M. and 10 P.M., and amounts to 0·53 millimetres. My formula** gives 0·60. Mr. Harris deduces 29·800 for the mean pressure 60 feet above the level of the sea, which agrees nearly with the observations at Somerset House; but there is some material discrepancy in the observations of *mean* height for different years.

* M. Bouvard gives 755·99 mm. reduced to 0° C. from eleven years' observation at Paris; M. Arago, 755·43 mm. from nine years' observation.

† Arago. ‡ Kindly communicated to me by M. Valz, of Marseilles.

§ The Royal Society Observations since Nov. 1837 (see Phil. Mag., xii. 204), may one day afford this, but the period is as yet rather too short.

‖ Last Report, p. 229. Mahlmann, p. 89.

¶ The results were partly communicated to the British Association in 1839 (see *Athenæum*, 14th Sept.). The following results, which are *corrected for temperature* and embrace three years, were communicated to me by Mr. Harris himself. The agreement of the three years is very satisfactory, so far as the form of the curves is concerned. See also British Association, Eighth Report, p. 22.

** Edinburgh Transactions, vol. xii.

152. Mr. Caldecott, astronomer to the Rajah of Travancore, has obligingly communicated to me the results of his observations in 80° 30′ N. lat., where he finds the oscillation from 10 A.M. to 4 P.M. to be ·109 English inches = 2·77 millimetres, whilst my formula gives 2·57. There appears to be some anomaly at the Cape of Good Hope, if the reductions with which Sir John Herschel has furnished me represent correctly the series of observations made at the Royal Observatory there. From 58 months' observations (lat. 33° 56′ S.), the oscillation is ·025 mm. = 0·64 mm. The formula would give 1·42 mm., or more than twice as much; a difference altogether improbable, or else indicating some remarkable local anomaly.

153. Colonel Sykes* finds the maximum atmospheric tide in the East Indies (mean lat. $18\frac{1}{2}°$, mean elevation 1800 feet), to be between 9–10 A.M. and 4-5 P.M., and to amount to ·107 inch =2·72 mm. by four years' observations. The formula gives 2·28 mm. Colonel Sykes finds the hours to be unmodified by elevation, and to be the same as in Europe and America. He has also shown such enormous irregularities in the results from different parts of India, and even in the same place at different times, as do not so much militate against any particular formula, as they show the impossibility of any one formula embracing such discordant conclusions†. Colonel Sykes has shown that the supposed interruption of the atmospheric tide during the prevalence of the monsoon has no existence‡.

154. Prof. Kämtz§ has made some interesting observations on the variation of the atmospheric tide with height|| in Switzerland, on the summits of the Faulhorn and Rigi, compared with Zurich and Geneva. The hours are nearly the same in all cases, 4 A.M., 10 A.M., 3 P.M., 9 P.M.

	French Lines.
The *mean* oscillation at Zurich and Geneva .	0·398
„ Faulhorn	0·119

* Philosophical Transactions, 1835. † Ibid., p. 176.

‡ An account has been published (Proceedings of the Royal Society, May 21st, 1840), since this report was written, of valuable Observations on the Barometer, by Capt. Thomas, at Alten, in Finn-marken, in lat. 70°; from which it clearly appears that the barometric oscillation is there *negative*, as my formula would indicate that it ought to be. I am bound to apply to the "Report" on Capt. Thomas's Observations published as above, the remark which I have made upon Colonel Sykes's paper, in the text, viz. that it is scarcely philosophical to expect that any formula should coincide more nearly with observations, than one year's observations do with another.

§ Poggendorff, xxvii. 345. See also Gautier on the Annual and Diurnal Variations of the Atmospheric Tide. *Bibl. Univ.*, N. S., xxiv. 124.

|| See former Report, p. 232, and my paper in Edinburgh Transactions, vol. xii.

Another series gives—

Mean oscillation at Zurich	0·286
„ Rigi	0·105

The two results agree very closely in assigning a value of the oscillation depending on the absolute pressure. M. Kämtz thinks that the diminution with height is as the diminished pressure, and may be expressed by $\frac{1}{300}$th of the change of pressure. Thus, at the equator, the oscillation (according to him) would cease at a height where the barometer falls to 115 lines, and afterwards, no doubt, would become negative, as I have formerly shown. The observations cited by Col. Sykes* confirm the general principle.

155. The cause of the diminution of the diurnal tide with height is no doubt this :—that the great vertical depth of air which exists between Geneva and the Great St. Bernard, for example, becoming heated by the action of the sun commencing at the earth's surface, a portion of air is raised *above* the upper station in the afternoon, which in the morning was *below* it; consequently this produces a diurnal tide in the higher regions, which has its maximum after the hottest part of the day, and which therefore counteracts the true diurnal tide.

156. On the subject of the lunar influence on the barometer, we may refer, in the first place, to the popular article by M. Arago, in the *Annuaire* for 1833†; who gives the results of Flaugergues, mentioned in our last report‡, which give a decided maximum at the last quarter, with which the observations of MM. Boussingault and Rivero, at Santa Fé de Bogota, agree. According to a late and complete reduction of the Paris observations by M. Eugene Bouvard§, we have a first maximum on the 8th day of the moon, and a second or *principal* one on the 22nd day; the *principal minimum* on the 13th, and a second on the 27th day. Here, therefore, we have, as above, a decided maximum about the last quarter. The oscillation is 1·78 mm. Mr. Snow Harris has arrived at the same result as respects the principal maximum‖, which may probably be considered as established. We shall return to this subject in treating of the fall of rain, and dependence of weather on the lunar phases.

D. *Barometric Variation with Height*¶.

157. I will add a few observations on this subject, especially

* Phil. Trans. 1835, p. 176. † P. 173. ‡ P. 234.

§ *Correspondance de l'Observatoire de Bruxelles*, tom. viii.

‖ Athenæum, Sept. 14th, 1839.

¶ Last Report, p. 236. Mahlmann, p. 119.

in correction or addition to those contained in my former report.

158. M. Bessel has given an Essay on the Theory of Barometrical Measurements*.

159. The important question of determining levels by observations of distant barometers, is materially affected by the now-admitted difference of mean barometric pressures at different localities; and it also appears that, unless these observations are steadily continued for considerable periods, they must be liable to serious errors. Thus M. Galle (the assistant astronomer at Berlin) has pointed out, in two interesting communications†, that in *certain situations* enormous errors of barometric measurements arise at certain seasons, which he ascribes to the influence of local winds. It is very plain, that if, from any cause, the monthly variation of mean pressure of which we have already spoken, follow one course at one station and another at a second, the height deduced from any barometric formula will also depend upon the season. This M. Galle has found to be most remarkably the case between Katherinenburg and St. Petersburg. The calculated difference of height varies with the season, having a maximum in summer and minimum in winter; it depends, in fact, on the Difference of Temperature of the two stations. The height is greatest when the difference of temperature is least; and when the difference of temperature changes its usual sign, the height becomes greatly exaggerated. Thus we have the following analogies:—

Diff. Temp. Reaum.	Katherinenburg above St. Petersburg, in Toises.
from — 2° to 0°	141
0 2	103
2 4	93
6 7	82

The differences of temperature again depend immediately on the prevailing wind, and therefore on the season. Such an anomaly is not observed between Kasan and Katharinenburg‡.

160. This anomaly is both important as a physical fact and in its consequences. The vast continental regions of Russia sustain aerial columns, which do not make hydrostatic equilibrium with one another. It affords a fresh reason for re-investigating the much-agitated question of the level of the Caspian Sea§, which may now probably be considered as set at rest by the results of

* Schumacher's *Astr. Nachr.*, No. 279. Poggendorff, xxxvi. 187.

† Poggendorff, xlviii. 58. 379.

‡ Humboldt, Ehrenberg, and Rose's *Reise*, i. 277, quoted by Galle.

§ See an elaborate paper by Lenz on this subject, Poggendorff, xxvi. 353.

the last Russian expedition, by whom the space between the sea of Asov (communicating through the Black Sea and Mediterranean with the ocean), has been accurately levelled, and the depression of the Caspian found to be real, but amounting to only 81·5 English feet *, instead of 334 feet, as formerly supposed †. But what is interesting is, that the barometrical observations made with the utmost care, and at multiplied intermediate stations (one German mile apart), confirm the older results obtained by the same means. The very same kind of anomaly as observed between Katherinenburg and St. Petersburg, occurs here, and even gives to the elevation of the Sea of Asov a negative sign at certain seasons. The Sea of Asov, though *further south* and *lower* than the Caspian, has a climate 30° Fahr. colder in the middle of January ‡.

161. There seems to be very little doubt that the Dead Sea lies also below the level of the ocean. The very discordant, but almost simultaneous results, obtained by different travellers §, lead us to admit the fact as probable, and even to conjecture that the depression may be considerable.

162. M. Kämtz || has given some very useful results as to variations of computed height depending on the hour of the day, which acts much in the way in which the season of the year affects barometrical measurements. The maximum calculated height occurs at noon, or soon after; the minimum, about 4 A.M. The effect is far greater than the atmospheric tide would produce, amounting to 21—27 toises upon 1100 (the difference of height of the Faulhorn and Zurich, or Geneva), and to 13 upon 700 (Rigi and Zurich). Hence it appears that Ramond's rule of employing the noon observations for deducing heights is not in this respect exact ¶.

163. We do not of course propose to give any results of barometrical measurements. The temperature of boiling water is not unfrequently employed, but seldom with sufficient instruments. It has several practical difficulties; amongst others, that of obtaining sufficient heat at great elevations, and in exposed situations, to cause water to boil. M. Hugi, of Soleure, in his enterprising Alpine excursions **, has used the boiling point of alcohol with good effect. It may seem surprising that this should be tolerably constant, but such I have assured

* Poggendorff, 1840, and Edin. Phil. Journal, July 1840.

† First Report, p. 239. ‡ See Galle, *ut sup.*

§ Edinburgh Philosophical Journal, 1840.

|| Poggendorff, xxvii. 345, and Dove's *Repertorium*, vol. iii.

¶ On the influence of winds on barometrical measurements, see Brandes, *Beiträge*, p. 216.

** *Naturhistorische Alpenreise.* 8vo. Solothurn, 1830.

myself by experiment to be the fact. Hugi states (what is very conceivable), that the boiling point of water *anticipates* the barometric indications by some hours; but he states (what is more difficult to understand), that the boiling point of alcohol harmonizes with the latter*.

III.—Humidity†.

A. *Hygrometers.*

164. No new hygrometer has been introduced of late years, so far as I am aware, at least no important novelty, but very considerable progress has been made in the right interpretation of results‡.

165. By far the completest historical treatise which I have seen on hygrometry and hygrometers, is a learned thesis by Suerman (different from the one already cited), entitled "*Commentatio de definiendâ quantitate Vaporis Aquei in Atmospherâ,*" &c.§, which also contains good figures, and many pertinent original criticisms.

166. As hygrometry essentially turns upon a right knowledge of the relations of heat and moisture, we may first observe, that a considerable number of attempts have been made (without new experiments) to express, by some simple formula, the relation between the temperature and pressure of vapour. The only experiments of any consequence that I am acquainted with are those of the Franklin Institute (America), conducted under the superintendence of Prof. Bache‖. They do not much surpass 10 atmospheres, and even there the difference is 6° Fahr. between them and M. Dulong's results, a difference which does not seem to be satisfactorily accounted for. M. Dulong's formula represents observations above 1 or 2 atmospheres better than those below; and there is reason to think that, whether from the mode of conducting the experiments, or some other cause, there is some solution of continuity in the law which expresses the relation of density and pressure somewhere near the point arbitrarily called the boiling point¶.

* *Naturhistorische Alpenreise*, p. 16.

† See last Report, p. 239, and Mahlmann, p. 129.

‡ "Jam vero lætior campus arridet quio recentiorum experimenta exponenda veniunt, qui, de vaporis natura longe certiores, multa simpliciorem tutioremque viam quam præcedentes physici, ingredi potuerunt."—Suerman, *Commentatio*, § 45.

§ 4to. Lugd. Bat. 1831, p. 123. For this, too, I was indebted to the late Prof. Moll.

‖ Report on the Explosions of Steam Boilers. Philadelphia, 1836, p. 76.

¶ The formula which the American Committee adopt to represent their results is (for Force corresponding to Degrees of Fahrenheit) $e = (\cdot 00333\, t + 1)^6$.

167. Spasky* has taken the trouble to ascertain whether the constants in Dulong's formula (viz. the factor of t and the exponent), might not be altered so as to represent the observations better, but he has obtained a very insignificant change.

168. Egen†, writing on the same subject, criticises the different formula, and gives one expressing the temperature in a series of successive powers of logarithms of the force or pressure.

169. Biot ‡, Schmeddink §, and Roche ‖, have all written on the same subject recently, and proposed new formulæ. Mr. Russell has proposed to adopt a modification of Dalton's scale of temperature, by which the elasticities may follow an accurately geometrical progression ¶. Mr. Lubbock** has deduced, from theoretical considerations, a formula sufficiently simple, and which represents, with extraordinary fidelity, the observations of the Commission of the Institute; less accurately those of Southern below 212°.

170. I mention these results as generally connected with the subject; the actual range of hygrometric observations requires such a formula to be used as shall best represent the elasticities under 212°.

171. The formulæ in use are (1.) that derived from the observations of Dalton and Ure; (2.) that deduced by Kämtz from his own observations††; (3.) the table calculated by Ivery's formula, founded on Ure's experiments; it is that given in the *second* edition of Daniell's Meteorological Essays, and adopted in the Royal Society's Instructions for the Antarctic expedition. Of these, Dalton's has best stood the test of time. Kämtz's is recommended by Kupffer ‡‡, but is condemned by Egen §§, Lloyd ‖‖, and Apjohn. In the first place, let us turn for a moment to the *data* of the problem.

172. The dew-point being obtained by the method of Dalton, or that of Daniell, the quantity of vapour in the air, and the ratio of the contained vapour to what *might* be contained in

* Poggendorff, xxx. 331. Instead of $e = (1 + 0{\cdot}7153\ t)^5$, he finds $(1 + 719\ t)^{4{\cdot}9987}$ for the elastic force, t being in cent. degrees.

† Pogg. xxvii. 9.

‡ *L'Institut*, No. 26, p. 222. Pogg. xxxi. 42.

§ Pogg. xxvii. 40.

‖ Silliman's Journal, xxviii. 363.

¶ Proceedings, Royal Society of Edinburgh, vol. i. p. 227.

** On the Heat of Vapours, p. 7. Lond. 1840.

†† M. Kämtz's first work on the subject was published at Halle in 1826. In the first volume of his Meteorology, p. 289, he has given an account of *original* experiments on which his formula is founded, which appears to differ very sensibly from the results in common use. This formula has had its constants more lately modified, as appears by M. Kupffer's citation of it. See below.

‡‡ *Bulletin de l'Acad. de St. Petersbourg*, tom. vi. No. 22.

§§ Pogg. xxvii. 25.

‖‖ Proceedings, Royal Irish Academy, 1840.

air under the circumstances* (which is the true expression for dampness), is at once obtainable from a table which shows the maximum force of vapour for each degree, and the number of grains in one cubic foot of space. But unfortunately the experiment is always a troublesome, sometimes an impracticable, and sometimes a fallacious one. Mr. Harcourt† has pointed out various mechanical circumstances which affect the appearance of a film of dew. To reduce a hygrometric observation to an *observation* simply, and not to an *experiment*, is the object of the moist-bulb problem, in which the refrigeration of a wetted surface becomes the index of the dryness. The theory is more troublesome, but the observation has every requisite of simplicity and consistency‡.

173. The moist-bulb problem was especially pointed out as one deserving careful solution in the recommendations of the first meeting of the British Association at York§, and they have been responded to in more than one quarter, so that we may now consider the moist-bulb problem as practically solved.

174. Even at that time the solution had taken a simple and exact form in Germany, and for the labours of Auguste‖, Bohnenberger¶ and Kämtz**, the British Association cannot probably claim any merit. The works of the two former are, I am sorry to say, still as unknown to me (by actual inspection), as when I wrote my former report.

175. A thermometer having a thin film of water surrounding it will take a temperature depending on the following circumstances:—The air in contact (whether it move quickly or slowly) gives to the film of water, which is converted into vapour sufficient in quantity to saturate the space which the air occupies, just enough of heat to vaporize that water, and the reduction of temperature will be accordingly. Thus, if the air (or space) be very dry, it will take up much vapour, but that vapour must have combined with much heat in order to change its state from water, and the temperature of the air in the (now) saturated

* When we speak of vapour contained in air, of course we are not to be understood to infer any combination between them.

† Phil. Mag., 3rd Series, vii. 409, and British Association, Fifth Report, Sections, p. 54.

‡ This method was the invention of Dr. Hutton, of Edinburgh, which M. Kupffer has erroneously attributed to Auguste (Instructions, &c., p. 32), and Mr. Prinsep to Leslie (Journal of Asiatic Society of Bengal, 1836, p. 399.).

§ Original edition, p. 49. These recommendations were drawn up by the author of the present report.

‖ *Uber die Fortschritte der Hygrometrie in der neuesten Zeit.* Berlin 1830.

¶ In the second volume of the Tubingen Nat. Hist. Society's Memoirs.

** *Lehrbuch der Meteorologie*, i.

space is lowered accordingly. Further, it will be more lowered if the air be rare, or the barometer low, because the air yields less heat. All these circumstances may be taken into account, and the elasticity of vapour existing in the air may yet be expressed by the following simple formula*:—

$$e'' = e' - m(t - t')\,\frac{b - e'}{B},$$

where t and t' are the readings of a *dry* and a *wetted* thermometer;

e' the maximum elasticity of vapour corresponding to t';

e'' „ „ „ to the dew-point;

b the observed height of the barometer;

B a standard barometric pressure (as 30 inches).

The concluding factor is usually small, and except at great heights may be neglected.

176. When e'', the elasticity corresponding to the dew-point, is found, the quantity of vapour existing in the atmosphere is known.

177. The chief value of a dew-point instrument is to enable us to determine *directly* the value of m, which the direct experiments on the specific heat of air leave under some uncertainty.

178. Conversely the specific heat of air may be determined from hygrometric observations. This has been done by Dr. Apjohn†.

179. The value of m manifestly depends upon the unit of elasticity, and upon the unit of temperature.

180. Dr. Apjohn, of Dublin, whose attention was directed to the subject by the suggestion of the Committee of the Association, has, in a series of interesting papers, tested the value of m in a variety of circumstances by his own experiments‡, and by those of others§. Assuming De la Roche and Berard's value of the specific heat of air, he finds m, for English inches of mercury, and for Fahrenheit's degree, to be $\frac{1}{87} = \cdot 01149$: *à posteriori* he has determined it—

(1.) from experiments on the dew-point . . . ·01151

(2.) „ on refrigeration in dry air . ·01150||

* This formula, employed by Auguste and Bohnenberger, coincides essentially with that of Ivory (Phil. Mag. lx. 80.), who first gave a proper theory of the moistened bulb hygrometer. His value of m is not far from the truth, being $\frac{1}{40}$ for cent. degrees, or $\frac{1}{72}$ for Fahrenheit.

† Irish Trans., Phil. Mag., and Brit. Assoc., Sixth Report. See also Suerman's Thesis.

‡ Phil. Mag., 3rd Series, vii. 266. 470. § Ibid., vi. 182.

|| Prof. Lloyd has ingeniously made this set of experiments the means of testing the accuracy of the tables of the force of vapour, and he prefers Dalton and Ure's calculated by Anderson.—Proceedings, Royal Irish Academy, 1840.

(3.) from experiments on refrigeration in air once saturated, then warmed . . . . ·01140

nearly coincident with one another, and with the theoretical determination.

181. Bohnenberger* had already obtained a value sensibly identical, which probably was not known to Dr. Apjohn at the time he made his experiments; for English inches and Fahrenheit degrees, he obtained—

First, from 56 observations . . . . . . $m =$ ·0114
Afterwards, from 45, which he preferred . ·011398

182. M. Kämtz, in a very valuable paper† on the results of his extensive observations in Switzerland, has given his formula in a slightly different form, but which indicates an almost precise coincidence between theory and experiment, both for the case where the thermometer is above freezing and below; for in the latter case equally the principle holds, only we must allow for the latent heat absorbed in liquefying as well as vaporizing the water. Including the barometric formula, M. Kämtz writes the second term of the formula for the elasticity thus:

$$- 0{\cdot}001004475\ (t - t')\ b,$$

b being the barometric height in French lines, the standard barometric height 336 lines, by which the co-efficient (which is for Reaumur's scale) has been already divided.

183. The above expression is the *theoretical* one *above* 0° R. The *theoretical* one *below* 0° R. is

$$- 0{\cdot}0009375\ (t - t')\ b.$$

184. These two numbers, deduced *à posteriori* from the Swiss observations, give

Above 0° R.	Faulhorn . .	·0010026	34 obs.
	Rigi	·001002506	31 „
Below 0° R.	Faulhorn . .	·000945014	15 „
	Zurich . . .	·0009995	11 „

from direct comparison with the dew-point.

185. I have given these numbers, that their coincidence may be perceived. Again, to compare them with Apjohn's and others, we may take those at the Faulhorn and reduce them to English measures and a mean barometric pressure, when we shall obtain

Above 32° Fahr. . . . . $m =$ ·0118
Below 32° Fahr. . . . . $m =$ ·0112

* Suerman, p. 88.

† Poggendorff, xxx. 33.

186. M. Kupffer*, though he adopts Kämtz's table of elasticities, after examining the experiments of Gay-Lussac, Bohnenberger, Auguste, and Erman, finally prefers this value of m,

$$\text{Above } 32^\circ \quad . \quad . \quad . \quad . \quad . \quad . \quad m = \cdot 01135$$

almost coincident with that of Bohnenberger and Apjohn.

187. A most elaborate paper has been published by Mr. Prinsep, of Calcutta, in the Journal of the Asiatic Society of Bengal†, on the wet-bulb problem, in continuation of the ingenious, but rather obscure ones, alluded to in the former report, as having been published in the "Gleanings of Science"‡. Mr. Prinsep states, that the notice taken of his former labours, in the First Report of the British Association, had stimulated him to resume the subject, and he has accordingly furnished us with a great many valuable test-experiments, which can nowhere be so well performed as in warm climates. Mr. Prinsep's original memoir will be consulted by those who wish to avail themselves of his valuable researches for the improvement of theory: it is not necessary to dwell upon those points where he seems to us to be less explicit, or historically not quite exact; and the great point is to be clearly satisfied that we have *now* obtained a sufficient interpretation of the indications of the moistened thermometer. When we find that Mr. Prinsep once more coincides with Dr. Apjohn's numbers, only *hesitating* whether to prefer $\frac{1}{84}$ to $\frac{1}{87}$ for the value of m, we are prepared to admit that this problem is, *practically* speaking, *completely* resolved; and this being the case, it is scarcely worth while to disentangle the various imperfect steps by which so happy a consummation has been attained, and the hygrometer rendered as commodious and as accurate as the common thermometer§. The leading steps of the generalization are these:—Hutton invented the method; Leslie revived and extended it, giving probably the earliest, though an imperfect theory; Gay-Lussac, by his excellent experiments and reasoning from them, completed the theory, *so far as perfectly dry air is concerned*; Ivory ex-

* *Bulletin de l'Académie des Sciences de St. Petersbourg*, vi. No. 22, for which I am indebted to Major Sabine.

† No. 55, July, 1836.

‡ The "Gleanings in Science" referred to in the original Report of the British Association, had been lent to me by Sir D. Brewster, to whom they had been sent. I afterwards communicated them to Dr. Apjohn.

§ In practice, I am inclined to prefer two separate thermometers to the differential one of Leslie, which requires besides, the use of a common thermometer, to take the temperature of the air. It seems preferable to have two thermometers arranged in one pocket-case, and in the event of fracture a single one may still be used. I have formerly adverted to the unnecessary introduction of the term psychrometer to express so simple a combination.

tended the theory; which was reduced to practice by Auguste and Bohnenberger, who determined the constant with accuracy. English observers have done little more than confirm the conclusions of our industrious Germanic neighbours; nevertheless, the experiments of Apjohn and Prinsep must ever be considered as conclusively settling the value of the co-efficient near the one extremity of the scale, as those of Kämtz have done for the other.

188. Of the papers of Dr. Hudson in the Philosophical Magazine*, and of Mr. Meikle, and of an anonymous author, in the Edinburgh New Philosophical Journal†, it is not necessary for me to speak, on the grounds just stated. The experiments of the latter have been compared with theory by Dr. Apjohn.

B. *On the Distribution of Vapour in the Atmosphere.*

189. Now that we have got a simple and intelligible hygrometer, we may hope to know more than we yet do respecting the distribution of vapour in the atmosphere. Accurate experiments are at present extremely rare; a few of the most interesting have been obtained by M. Kämtz. The greatest dryness he has observed was on the 28th September, 1832, on the summit of the Faulhorn, the barometer 247·4 French lines. At 9 A.M. the temperature of the air was 6°·9 R., the moist thermometer fell to 0°·1 R. The computed dryness is 9 per cent. of saturation‡. Clouds he has always found to be perfectly damp when fully immersed in them, confirming the result of Saussure, which has been called in question§.

190. It has commonly been supposed that dryness increases as we ascend; yet it is also certain, that at a certain elevation clouds are more common than at any other. Accordingly, Kämtz finds that, whilst in dry weather the higher regions are drier than below, in damp weather the reverse is the case; he finds that, if we consider the *absolute* elasticity of vapour at a given place, there are two maxima and two minima daily; but if we consider the relative humidity, or proportion existing to the capacity of saturation, there remains but a single maximum of dampness at 4–5 A.M. (in June), and one minimum at 2 P.M.

191. The absolute quantity of moisture existing in the air is greatest at the equator, and diminishes towards the poles. M. Kämtz, from the experiments of Beechey and others, gives the following formula‖ for the North Atlantic:—

* Phil. Mag., 3rd Series, vii. viii. ix.

† xv. 273; xvii. 98. 330.

‡ Poggendorff, xxx. 71.

§ Poggendorff, xxx. p. 53.

‖ Poggendorff, xxx. 59.

$E_\phi = 0{\cdot}1370 + 8{\cdot}9004 \cos^2 \phi$ in French lines, where E_ϕ is the elasticity of vapour in lat. ϕ.

IV.—Wind*.

192. The immediate cause of wind is the inequality of pneumatic pressure in the atmosphere, occasioned by differences (permanent or variable) of temperature.

193. Of Permanent Differences, the most important is the warmth of the equatorial regions compared to the polar. The combination of this cause with the rotation of the earth is the well-known cause of the trade winds; and, we may add, of the prevalent west winds in northern latitudes, as well as of the counter currents observed at certain elevations.

194. Of Variable Differences of temperature there are very many;—as (1) the variable temperature of any spot, occasioned by the annual change of position of the sun respecting it; (2) a similar variation for different hours of the day or night; (3) a variation due to the continental and insular character of climate affecting the annual temperature curve; (4) a similar influence of the solid or fluid, and more or less heat-absorbing, character of the surface, in varying the distribution of temperature during twenty-four hours; (5.) the variable nature of surface depending on elevation, such as the presence of mountains, which receive heat from and part with it to the adjacent plains, according to different laws.

195. All these causes produce their peculiar and local effects, which it may be sufficient to advert to in the most general way. To the *first* cause is due the variation in the position of the limit of the trade winds at different seasons. To the *second*, the *probable* tendency of the warmth at the part of the earth's surface, on which, in his diurnal course, the sun has just exercised its greatest energy, to attract the colder air from the parts of the earth on whose horizon he is just appearing. To the *third*, are attributable the very important effects of the *monsoons*, the local variations of the trades (as on the coast of Africa and Mexico†), the prevalence of east winds in Europe in spring, and many similar phænomena. To the *fourth*, the recurrence of land and sea breezes in all climates, especially between the tropics. To the *fifth*, the very remarkable but little-noticed diurnal phænomena of hill and valley breezes, occurring with great regularity in mountainous countries having a pretty uniform climate (as in the South of Europe), and

* See former Report, p. 246. Mahlmann, p. 155.

† See Capt. Hall's Fragments of Voyages and Travels, 2nd Series, ii., and Daniell's Meteorological Essays, 2nd Edition.

which, especially in their connexion with moisture, have a most important influence on climate.

196. All these phænomena deserve a more careful examination than they have received, with a philosophical view of referring them to their common cause. What has been done in this way we will presently notice. But first, we will say something as to means of investigation.

A. *Anemometers.*

197. In my former report I remarked, that if anything were to be done in the way of anemometrical observations, it must be by the use of self-registering instruments. Two such have been invented, and pretty extensively used in this country.

198. Mr. Whewell* has described an anemometer proceeding on the ingenious principle, that the meteorological importance of a wind blowing in a given direction is not to be estimated by the number of days or hours that it blows in a given direction, but by the compound ratio of the time and force. This he endeavours to obtain by causing a pencil to describe a vertical line with a velocity proportional to the number of turns of a vane with which it is connected, whilst at the same time the pencil is carried round a cylindric surface by an apparatus like that which guides a windmill, so as to point out the azimuth of the wind. The length of line described by the pencil between two given azimuths shows the integral effect of force and time for that interval. The instrument has been worked with very considerable success at Cambridge, under the directions of Professors Whewell and Challis †, at Plymouth by Mr. Southwood ‡, at Edinburgh by Mr. Rankine § and myself, and in other places. From its construction (friction being the antagonist force or regulator), perfect comparability cannot be expected.

199. Mr. Osler, of Birmingham, has invented and constructed an ingenious but complicated apparatus for measuring the force and direction of the wind at any moment, and for keeping a register of these particulars in the absence of the observer ||. It consists of a very powerful vane, which carries round the stalk to which it is affixed; this stalk terminating in a pinion, moves a rack connected with a pencil, which describes upon paper the

* Cambridge Transactions, vol. vi. part ii.

† British Association, 7th Report, Sections, p. 32, and Camb. Transactions.

‡ Ibid., 8th Report, p. 28. § Edin. Trans. xiv. 359.

|| British Association, 7th Report, Sections, p. 33, and "Description of a Self-Registering Anemometer and Rain-Gauge." 4to. Birmingham, 1839, with a plate. Some parts of the apparatus have been more lately modified.

variations in the *direction* of the wind, the paper being carried uniformly along beneath the pencil by means of clockwork, so that the pencil describes a Curve of Direction of the Wind. The force is registered by means of a plate one foot square connected with the vane-stalk by a jointed parallelogram; which plate is pressed against a spiral spring in such a manner as to indicate the force of the wind by the antagonist force of the spring in pounds. To indicate this upon the same sheet of paper before mentioned, and with regard to time, a thread connected with the pressure plate is conveyed through the axis of the vane-stalk (which is hollow), and then turning over a pulley, pulls a pencil up or down as the intensity increases or diminishes, leaving an intelligible tracing on the paper, from which the mean pressure may be tolerably estimated*. The fall of rain is registered by a peculiar contrivance upon the same sheet, so as to indicate its amount and distribution over the twenty-four hours. The expense of the instrument and its liability to derangement are the chief objections to it; it is evident that so many objects cannot be gained without considerable complication†. One of these anemometers has been worked for a considerable time at Birmingham, and another at Plymouth‡. One has just been established at Edinburgh, and others, it is believed, have been sent to Ireland and America.

200. Mr. R. Adie, of Liverpool, has contrived a statical wind-gauge, in which the maximum pressure is pointed out. It is on the principle of a gasometer with a moveable top, over water, and the pressure of the wind is introduced by a tube below. The pressure is indicated by a hand connected with an axis, which is turned as the moveable top rises against a graduated resistance§.

B. *Phænomena of Wind generally.*

201. It is rather remarkable that of late years several persons should independently have arrived at partial solutions of the great and complicated problem of aerial currents, their distribution and causes. A few of the simpler admitted facts have al-

* As every instrument upon this construction must necessarily act by impulsive starts, the *statical* gradation cannot possibly give the actual force of the wind, but it is difficult to suggest a better measure.

† This instrument is in every respect so much more complicated in its parts and delicate in its adjustments than Mr. Whewell's anemometer, that it is difficult to understand how the latter comes to be described in the Royal Society's Instructions (p. 71.) as "more complex in its construction, and practically more liable to derangement."

‡ See Reports of the Ninth Meeting of the British Association.

§ See a figure in Dr. Traill's article on Physical Geography, from the *Encyclopædia Britannica*, 8vo, p. 197.

ready been mentioned, which serve to explain the more formal modifications of wind by a combination of the principles of rarefaction by heat, and the mechanical rotation of the globe. The particle of air, thus drawn toward the equatorial regions by the rarefaction permanently produced there by the sun's verticality, lags behind the parallel of latitude over which it moves, having the velocity due to a higher latitude from which it has come. That there *must* be a return current is not only evident to common sense, but its existence is made evident by the drift of clouds in the neighbourhood of the tropics, and by observations at great elevations; not to mention that the prevalent S. and S.W. winds of our latitudes appear to be nothing else than portions of this superior return current, which, in this stage of its progress, falls again to the surface of the earth, possessed of the excess of velocity of a more southern parallel.

202. These doctrines are now generally held, but there have been various attempts made to carry out the theory and to generalize the facts further, even as respects the apparently capricious changes of wind in this most anomalous region of the earth's surface. It even appears probable that our forefathers knew more on this subject than is generally admitted now, and the sagacious guesses of the seventeenth century may be brought in support of the *probable* theoretical conjectures of the nineteenth.

203. Professor Dove, of Berlin, author of several original researches in meteorology, optics, and magnetism, and editor of a valuable scientific work of reference*, has published a series of elaborate memoirs more or less connected with the theory of wind†, of which he has more lately published a compend ‡, but whose labours on this subject seem to be little, if at all, known in this country. This perhaps is to be attributed to the want of a perspicuous analysis of his views by some one who would undertake clearly to state, how far they are original and how far combined from those of others, how far they are to be considered hypothetical and how far founded upon demonstration. We feel the want of some such guide in turning over Prof. Dove's three hundred and forty-four closely-printed pages, and also in the writings of his countrymen who have acted as commentators§. I am by no means satisfied that I am so thoroughly possessed of his views as to give *all* that Prof. Dove claims to

* *Repertorium*, of which 3 volumes are published.

† A list of 14 memoirs contained in Poggendorff's Annals between the 11th and 36th vols. will be found in his "Untersuchungen," p. viii.

‡ *Meteorologische Untersuchungen*, von H. W. Dove. Berlin, 1837. 8vo.

§ Fechner, in his *Repertorium*, vol. iii.; Kämtz, in his *Meteorologie*, i. 254; Mahlmann, in his enlarged Translation of my last Report, p. 155.

establish, but in stating briefly what I understand to be his fundamental positions, I shall at least have a better chance of rendering myself understood, than if I confined myself to the easier task of translating passages from the original works.

204. Considering first the simple phænomenon of the *direction of the wind*, apart from all others, it appears for ages to have been a belief that when the wind changes it does so in a *constant direction*, which is that of the hands of a watch, which for brevity we will call a Right-handed Rotation. M. Dove contrasts, not unaptly, the two following passages, one from Bacon, in the commencement of the 17th century, the other from a French physical writer of the 19th. The former says, "Si ventus se mutet conformiter ad motum solis, non revertitur plerumque aut si hoc facit fit ad breve tempus;" the latter, "On a cru remarquer que dans certains lieux les vents se succedent dans un ordre déterminé; mais ces observations présentent encore trop d'incertitudes pour qu'il nous soit permis de les discuter ici". The clear evidence which Dove produces of the opinion of observers of various countries during a space of two hundred years, that the more frequent and more permanent rotations of the wind are right-handed (in this hemisphere), give much support to his theory*. It is important to add, that the phænomena of the trade winds and monsoons enter as part of the expression of his general law of rotation (*das Drehungsgezetz des Windes*).

205. It is very remarkable, from its connexion with a different inquiry presently to be noticed, that in the Southern Hemisphere the *Law of Rotation is inverted*, the movement of direction is Left-handed. In the Northern Hemisphere the order of winds is

S., W., N., E., S.

In the Southern Hemisphere,

S., E., N., W., S.

Of these circuits, the quadrants from S. to W. and N. to E. in the Northern Hemisphere, and from N. to W. and S. to E. in the Southern Hemisphere, are oftener traversed in an inverted order than the opposite quadrants†.

206. This, however, is only a small part of M. Dove's investigation, for he aims at showing that this law of succession thus determined, renders a certain order of meteorological phænomena of every kind indispensable, and he has laboured to assign

* *Meteorologische Untersuchungen*, p. 132. It is important to observe, that the direction of rotation here mentioned has no reference to the rotatory movement of the aerial particles themselves, which will be referred to in the next section.

† *Meteorologische Untersuchungen*, p. 129. It is to be observed, that this Law of Rotation especially applies to *extra-tropical* regions, where the mixture of equatorial and polar currents is most complete.

for each hemisphere an invariable concomitance of the meteorological phænomena of temperature, pressure, humidity and rain for every direction of the wind. This research was indeed by no means new. Von Buch had shown the dependence of the barometer on the direction of the wind; even the poets could distinguish the thermal and hygrometric characters of Boreas and Zephyr; and it is easy to see that as far as the characters of North and South go, these particulars must be altered in the southern hemisphere. In my former report I have shown, from the researches of the German meteorologists, that the mean direction of the wind for the whole year depends on the climate*, and I might have added that the season exerts an important influence:—

207. Thus at Berlin the mean direction of the wind is †

		Proportion of E. to W. Winds.	Proportion of N. to S. Winds.
Winter	S. 33° W.	100 : 137	100 : 190
Spring	S. 73° W.	100 : 132	100 : 113
Summer	N. 83° W.	100 : 277	100 : 85
Autumn	S. 50° W.	100 : 160	100 : 167

Each season therefore has its predominant wind, as it has its characteristic temperature, pressure and moisture. It is Prof. Dove's object to prove that these follow as cause and effect, and hence that any law affecting the succession of winds must affect the succession of other meteorological phænomena. It must be owned that the following table of one year's observations at Calcutta give a strong probability to the *general* mutual dependence of these phænomena upon one another in those regions, where atmospheric laws are usually exhibited with vast disturbance, and therefore more correctly (at least in proportion to the time that the observations have been continued).

Month.	Temp. Fahrenheit.	Rain, Inch.	Barom. Inch.	Wind. Direction reckoned from S. by W.	Wind. Approx. Direction.
January ...	66·6	.....	30·08	156°	N.N.W.
February .	75	2·9	30·02	80	W.S.W.
March ...	79	0·5	29·95	355	S.
April	82·5	8·0	29·83	337	S.S.E.
May	86	6·0	29·77	348	S.S.E.
June	83	24·4	29·58	321	S.E.
July	83	12·8	29·59	314	S.E.
August ...	83	9·3	29·62	299	E.S.E.
September.	83	11·7	29·71	285	E.S.E.
October ...	83	1·4	29·91	94	W.
November.	75	0·5	29·98	118	W.N.W.
December.	69	....	30·01	135	N.W.

* P. 246.

† From the Observations of Beguelin, for 17 years. See Kämtz and Mahlmann.

208. "Since 1827," says Prof. Dove, "I have published a series of Memoirs in Poggendorff's Annals, in which I have sought to prove that the totality of the non-periodic meteorological changes of our latitudes reduces itself to a fundamental phænomenon, which I have called the Law of Rotation of the Wind. The fact of a regulated variation of the direction of the wind *(regelmässigen Ueberganges der verschiedenen Windesrichtungen)* observed centuries ago, yet often disputed, stood isolated from the generally acknowledged, if not sufficiently proved, influence of the winds' direction upon the pressure, temperature and humidity of the atmosphere. If, then, the so-called Irregular Variations are nothing else than the transition or passage of the barometrical, thermal and hygrometrical values of the winds into one another, it is clear that the laws of these variations can only be known by ascertaining the laws which connect the mean variations of the wind's direction with the distribution of pressure, temperature and moisture for the different points of the compass*". Such nearly, in the author's words, are the objects of his more laborious investigations; and to the construction of a barometric compass-card, a thermometric compass-card, and so forth, a series of memoirs is devoted. When by this means any mean series of meteorological changes becomes interpretable in terms of wind-azimuth, it is easy to see that new checks may be obtained for the fundamental law of rotation.

209. To pursue the course of M. Dove's laborious research is out of the question. We must content ourselves by giving a specimen of his conclusions†. In the *Northern* hemisphere

The *Barometer* falls during E. S.E. and S. winds; passes from falling to rising during S.W. and rises with W., N.W. and N. winds, and has its maximum rise with N.E. wind.

The *Thermometer* rises with E., S.E. and S. winds; has its maximum with S.W., and falls with W., N.W. and N. winds; its minimum is N.E.

The *Elasticity of Vapour* increases with E., S.E. and S. winds; has its maximum at S.W., and diminishes during the wind's progress by W. and N.W. to N.; at N.E. it has a minimum.

210. What has now been stated for the Northern hemisphere may be transferred to the Southern by changing N. into S., N. W. into S.W., &c., throughout.

211. These views of Dove have not been received altogether

* *Untersuchungen* (Pref.).

† *Untersuchungen*, p. 140.

without discussion. The mutual dependence of meteorological phænomena in a general way can hardly be disputed, but the fundamental Law of Rotation has been denied by Schouw, who has made this subject his particular study*. The subject now attracts considerable attention in Germany†, and the indications of anemometers, like Osler's, are well adapted to put it to the test.

C. *Phænomena of Storms*‡.

212. The ingenious observations of Franklin on the travelling of storms opposite to the actual movement of the wind which produced them, led to the supposition of local rarefactions and the sudden rush of wind from all quarters to supply the vacuity. The enormous linear velocity of the aerial particles required to produce the observed effects, to which might be added the difficulty of conceiving this propagation of disturbance to continue for days together, and to pass over hundreds or thousands of miles, with unabated intensity, led Colonel Capper to suggest in 1801 §, that the velocity of the wind at any point was chiefly due to the velocity of rotation of a vortex of fluid, combined probably with a progressive motion. Prof. Mitchell, of America, seems to have retrograded when he assigned to the gyration a vertical plane of motion||; but he was speedily followed by Redfield, who, doing all justice to those who preceded him, established Colonel Capper's doctrine by a diligent appeal to facts¶. Mr. Redfield has been fortunate also in having a European fellow-labourer in the same field, who has been equally candid in his acknowledgements of what he borrowed from America. Colonel Reid, in a handsome and elaborate work**, has maintained the same views, and supported them by an examina-

* See Kämtz, i., 257, and Pogg. xiv. 546. See also Schouw's extensive Essay on the Winds of Europe, "*Beiträge*", &c., p. 1—115.

† See Galle's papers on the Extension of Dove's Law to the Southern Hemisphere. Poggendorff, xxxi. 465 ; xxxviii. 472.

‡ First Report, p. 248.

§ In a work on the Monsoons and periodical winds, quoted by Redfield, Reid, and others.

|| Silliman's Journal, 1831, xix. 248.

¶ His first paper is in Silliman's Journal, 1831, xx. 17. There is a reply to him by Mitchell in the same volume. See also London Nautical Magazine, April, 1836, and Jan. 1839, and Silliman, xxx. 115.

** On the Law of Storms 8vo. London, 1838. An interesting review of this work, and of the previous labours of Redfield, will be found in the Edinburgh Review, lxviii. 406, to which those readers who wish a popular compend of the subject are referred. Since these pages were written, Prof. Dove has explicitly claimed the credit (Phil. Mag., Nov. 1840,) of having first in recent times asserted the revolving and progressive character of storms, and their opposite character in the two hemispheres.—Compare *Pogg.* xiii. 596.

tion of the courses of many hurricanes recorded in ships' logs, which he has projected on excellent charts. The theory of Colonel Capper proposed for the storms of the eastern hemisphere is found to be not less applicable to the terrific tempests of the West Indies, where these gyratory movements appear commonly to take their rise, *invariably revolving from right to left*, which at the same time *progress* in a straight or curved path, usually occupying a space of from 100 to 500 miles in diameter. These rotatory movements commence in tropical latitudes usually near the West India Islands; they move at first in a westerly and continually more northerly direction, until they reach a latitude of about 30°, when they turn rather abruptly towards the north-east. It is impossible not to believe that the path of these storms is mainly determined by the configuration of the American continent*.

213. The fall of the barometer, especially near the central parts of the storm, is accounted for by the action of centrifugal force.

214. It is very evident that the direction of the wind to a stationary observer, whilst one of these vortices is passing over him, will vary in a manner depending on his position with respect to the axis of the storm. If the centre pass rigorously over his station, he will experience a gale first in one direction and then in a directly opposite one, without any intermediate points of the compass; as an observer is stationed on one side of the axis or the other, a little reflection will clearly show that the apparent change in the wind's direction will follow opposite courses in the one or other position. This and many other deductions are fully made by Redfield and Reid; we only mention it just now in order to point out that this, at all events, must be considered an essential exception to Dove's law of rotation.

215. There is, however, a remarkable analogy to Dove's law in one respect, which is, that *the direction of rotation of storms is opposite in the two hemispheres*, being right-handed in the southern. This important fact was deduced by Redfield from his hypothesis that storms are produced by the mingling and collision of the superior equatorial stream with the polar stream or trade winds. Colonel Reid has given great support to this view by tracing some storms of the southern tropical regions.

216. Not the least important and interesting part of this inquiry is the deduction of practical rules for steering *out of* instead of *into* these vortices, an application distinctly pointed out by Col. Capper as well as his successors; but this does not concern us at present.

* See Colonel Reid's Charts, iii., v., vii.

217. The theory of Capper, Redfield, and Reid has not been received without opposition. Mr. Espy*, in particular, advocates the Franklinian doctrine of the progression of wind in radial lines; and he has received the powerful support of Prof. Bache, of Philadelphia, who has described, in great detail, a tornado† which occurred in New Brunswick in 1835, and from which he finds no proof of rotation. Mr. Milne‡ has traced, I think satisfactorily, the rotatory character of two remarkable storms which passed over the British Islands in November, 1838, accompanied with an extraordinary depression of the barometer of a very local character. M. Arago is disposed to admit, that there may be hurricanes of both characters, and, consequently, observations irreconcileable with either hypothesis singly§.

V.—Clouds—Rain||.

218. The theory of the suspension of clouds, one of the most interesting in the whole range of meteorology, has received no additions, nay, it can hardly be said to exist. That clouds consist of distinct particles is undoubted, from optical phænomena, and from direct observation¶; the error seems to be, to consider these as so many independent molecules, whereas they are no doubt connected by the most definite laws of force, and constitute *masses* whose density has no necessary connexion with that of their integrant *parts*. No one can observe the *character* of clouds—for instance, the well-formed cauliflower-

* Journal, Franklin Institute, October, 1836. Not having been able to procure this journal, I cannot refer to the contents more particularly. Mr. Espy maintains a peculiar physical theory of storms, which, since this report was written, has been brought in several forms before the British public.—See also Silliman, xxxix. 120. Dr. Hare has published, in the American Philosophical Transactions, and in Silliman's Journal (vol. xxxviii.), some papers respecting tornadoes, in which he appears to assign to them an electrical cause. Major Sabine has referred me to a clear and able analysis of the effects of the storm of the 20th December, 1836, by Mr. Loomis, in the first part of the 7th vol. of the American Transactions (which had not reached Scotland when this report was written), who appears to infer, in that particular case, a rotation round a horizontal axis like that imagined by Mitchell. The paper is highly worthy of consultation.

† Trans. American Phil. Soc., v. 407. It seems rather singular, that the name of tornado or whirlwind should be applied, by common consent, to a storm not having the rotatory character. Mr. Redfield denies Mr. Espy's and Prof. Bache's conclusions (Nautical Magazine, January, 1839, p. 6.). See also the Report of the Newcastle (Eighth) Meeting of the British Association, where Colonel Reid and Prof. Bache were present.

‡ Edinb. Trans., vol. xiv. § *Comptes Rendus* (Paris), vii. 707.

|| Former Report, p. 249. Mahlmann, p. 185.

¶ Since writing the former report, I have satisfied myself of the existence and some of the phænomena of Saussure's (so called) vesicular vapours.

headed cumulus contrasted with the flaky cirrus—without being persuaded of the fact, that clouds are not unorganized assemblages of watery particles in a state of extreme division.

219. With respect to the fall of rain, by far the most interesting contribution to this part of meteorology, took its origin at the rise of the British Association. Prof. Phillips, by his careful experiments on the fall of rain at different elevations at York, and his admirable deductions from them, has (I think) completely established the cause of the diminished fall of rain, as we ascend in the atmosphere (vertically above the soil). M. Boisgiraud *aîné*, of Toulouse*, was, I believe, the first in recent times† to maintain that this is due to the *gathering* of the drop as it descends, chiefly in consequence of the cold which it possesses, due to the height from which it has fallen, and also to the considerable dampness of the atmosphere at such times. This, the experiments of Mr. Phillips and Mr. Gray entirely confirm, and I think demonstrate‡.

220. For 12 months (1833–34) the fall of rain at York was as follows:—

Height above Ground.	Rain in Inches.
0 feet	25·706
44 „	19·852
213 „	14·963

The diminution was, therefore, 41·8 per cent. for 213 feet.
„ 22·8 „ 44 „

which is pretty nearly as the square root of the height. This proportion does not hold for different seasons; and though the formula $m\sqrt{\text{height}}$, originally proposed by Mr. Phillips (m being a function of the air-temperature), is a tolerable approximation, it does not appear to be an accurate one. Nor indeed have we any reason to suppose that so simple a law should express the effect, on the author's own hypothesis, since (admitting that the rain-drops have attained a terminal velocity) the deposition on the drop must involve the size of the drop, the dryness of the air, and the decrement of temperature in the atmosphere in a very complicated manner§.

221. Admitting, however, for a moment, Mr. Phillips's ori-

* *Annales de Chimie*, xxxiii. 417.

† Prof. Bache, of Philadelphia, has claimed, with reason, for Dr. Franklin, the merit of first suggesting the explanation, so far as the imperfect science of his time would fairly allow him to do.—Journal, Franklin Institute, vol. xvii. 1836.

‡ British Association, 3rd Report, p. 401; 4th Report, p. 560; 5th Report, p. 171.

§ The optical phænomena of the rainbow, to which we shall presently advert, confirm, in a remarkable manner, the increased size of drops in falling. —See Arago; *Annuaire*, 1836, p. 301.

ginal approximation, we think that he has fully made out his main point; for he has shown* that the value of the co-efficient m depends upon the dryness of the air, at least that it is very nearly inversely as the mean daily range at any season, a datum which, in a good degree, indicates the relative dryness; although without direct hygrometrical experiments the investigation must be considered as incomplete. Mr. Phillips desires that these experiments should be further pursued at points where three rain stations, vertically above one another, can be procured, and he has given instructions for making such observations†.

222. Prof. Bache, of Philadelphia, has shown the very material influence which the eddies of air surrounding a station, such as a tower or steeple, exert upon the fall of rain, depending on the position of the gauge‡. Mr. Phillips is at present engaged in an ingenious series of experiments, to estimate and eliminate these disturbances.

223. An admirable list of rain-gauge experiments, in different parts of the earth's surface, is given in Prof. Muncke's article on Rain, in Gehler's *Physikalisches Wörterbuch*§, an elaborate treatise, which appears to exhaust the literature of the subject.

224. It appears from the Report of the Birmingham Meeting of the British Association, as given in the *Athenæum* journal‖, that doubt has been thrown upon the statement of the remarkable fall of rain cited in my former report¶. I was not present at either of the discussions alluded to; I therefore take this opportunity of stating the authority upon which these very surprising falls of rain were admitted into my report—authority so ample, that, as a historian of science, I could not have omitted them, improbable as they do most certainly appear.

225. The fall of 30 inches of rain within 24 hours took place at Genoa** on the 25th October, 1822. An assertion to this effect having appeared in a Genoese newspaper, the editors of the *Bibliothèque Universelle* wrote immediately to make the necessary inquiries as to an observation so unprecedented. The reply, which they obtained from M. Pagano, "observateur exact," is given at length in this journal††, and is, I think, by no means the less satisfactory because it was obtained by the most inartificial of rain-gauges:—"Deux sceaux de bois, presque cylindriques, dont l'un de vingt-quatre et l'autre de vingt-

* British Association, Third Report, p. 410.

† Ibid., 5th Rep., p. 178. ‡ Ibid., Eighth Report, Sections, p. 25.

§ Vol. vii. Part II. p. 1309. Leipzig, 1834.

‖ 31st August, 1839, p. 658. ¶ P. 252.

** Not *Geneva*, as stated by a printer's oversight in the former report; the MS. was correct.

†† Vol. xxii., *Partie Physique*, p. 67.

six pouces de hauteur, qui m'avoient servi pour quelques expériences sur la vendange étoient restés vides dans mon jardin. La pluie de Vendredi 25 Octobre, n'avoient pas encore cessé de tomber, que déjà ils en étoient remplis." He then proceeds to state on what grounds he infers that 4 inches more of rain fell after the largest vessel was filled, making a total of 30 French (32 English) inches, and then adds a statement of several facts, to show that the effects of this deluge in the neighbourhood bore a proportion to the magnitude of the cause. M. Arago, quoting the result, adds, " Ce résultat inouï inspira des doutes à tous les météorologistes; ou soupçonnait une erreur d'impression; mais M. Pagano, observateur exact, a écrit aux rédacteurs de la *Bibliothèque Universelle,* une lettre qui *met le fait hors de toute contestation**."

226. Fortunately, however, this *local* deluge (for it appears by the letter of M. Pagano to have extended but a very short distance), is nearly rivalled by a similar fact recorded in the South of France by an experienced observer (who seems to have been in the practice of measuring the fall of rain for twenty-three years at least), M. Tardy de la Brossy, of Joyeuse, Dép. de l'Ardêche. M. Arago, who records the observation, and gives it the weight of his authority, does so in these words:—" Le 9 Octobre, 1827, dans l'intervalle de vingt-deux heures, il est tombé dans la même ville de Joyeuse, 29 pouces 3 lignes d'eau (*vingt-neuf pouces, trois lignes*); j'écris le résultat en toutes lettres *àfin qu'on ne croie pas à une faute d'impression*†." When I add that these two results, surprising, and perhaps unexampled, as they are in the history of science, have, on account of the testimony by which they are established, been received not only in France‡ and Switzerland§, but in Germany|| and England¶, I conceive that they are undoubtedly entitled to stand part of the history of meteorology**.

227. I proceed to add a notice of a few other remarkable falls

* *Annales de Chimie*, xxvii. 207. † *Annales de Chimie*, xxxvi. 414.

‡ By Arago and Pouillet (*Phys.* ii. 758.).

§ By the Editors of the *Bibliothèque Universelle.*

|| By Muncke (Gehler, vii. 1240.), Kämtz (Meteorology, i. 421.), and Mahlmann (Abriss. 200.).

¶ *Encyclopædia Metropolitana*, Art. Meteorology, p. 120.

** Mr. Espy has referred me to the fourth volume of Silliman's Journal for an account of a shower hardly less surprising. At Catskill (U. S.), Mr. Dwight ascertained that on the 26th July, 1819, between half-past 3 P.M. and 11 P.M., that is, in *seven and a half hours*, there fell into an empty barrel placed in an open space *eighteen inches* of water. A tub $15\frac{1}{2}$ inches deep, and nearly cylindrical, was filled before sunset. Since writing the above, another fact of the same character has come to my knowledge. On the 25th Nov. 1826, *thirty-three* inches of rain fell at Gibraltar within *twenty-six* hours. This information I received from Professor Jameson, who believes that he had it from the late Col. Imrie.

of rain, though there is nothing on record comparable to the two preceding ones. Flaugergues, the eminent meteorologist of Viviers, obtained, on the 6th September, 1801, 13 inches 2·3 lines (14½ English inches) of rain in *eighteen hours**. On the 20th May, 1827, there fell at Geneva 6 inches of rain in *three hours*†. At Perth, on the 3rd August, 1829, there fell ⅘ths of an inch of rain in half an hour‡. On the 22nd November, 1826, I observed, at Naples, a fall of $\frac{9}{10}$ths of an inch of rain and hail in *thirty-seven minutes*§.

228. Were the equatorial records of the fall of rain as minute in respect of *distribution* as of total amount, we should doubtless have records of enormous falls within twenty-four hours. None so recorded, that I am aware of, approach the results at Genoa and Joyeuse. From the total quantities measured, it is evident that the result, for particular days, must be enormous. Don Antonio Lago observed, at San Luis Maranham (2½° S. lat.) a fall of *twenty-three feet*, 4 inches, 9·7 lines of rain in a year‖. Roussin states¶ (his account is confirmed), that at Cayenne (5° N. lat.) in February, 1820, there fell, in *ten hours*, 10·25 inches of rain; and between the 1st and 24th February, *twelve feet* 7 inches. From observations in the Ghauts, it appears that in the eastern hemisphere, in lat 18° N., 302·21 inches of rain have been measured**, a quantity exceeding that stated on the authority of Roussin, and which was once considered almost incredible; and of this quantity (25·2 English feet) nearly 10 feet fell in the month of July alone.

229. I have formerly stated, that the fall of rain *increases* on mountains††; and the following statement of Schubler, as to the fall of rain at three stations, confirms the fact‡‡:

	Height.	Depth of Rain§§.
Tubingen	1000 feet	3572
Schaichhof	1576 ,,	3856
Alp Genkingen	2400 ,,	5513

* *Bibliothèque Universelle*, viii. 132, quoted in Gehler.

† *Ann. de Chim.*, xxxvi. 414. The mean *annual* rain at Geneva is only 30 inches.

‡ Edinburgh Journal of Science, New Series, iii. 368.

§ I do not know whether there exists a record of the fall of rain at Clermont, on occasion of the catastrophe of the Valley of Royat, a few years ago; the amount, I presume, must have been very great, judging by the effects. M. Quetelet has recorded a remarkable fall of rain in Belgium (*Comptes Rendus*, viii. 980.).

‖ Humboldt, quoted by Muncke.

¶ Silliman's Journal, iv. 375., quoted by Muncke.

** Communicated by Colonel Sykes, at the Ninth Meeting of the British Association.—*Athenæum*, p. 658. Prof. Stevelly's inference from these results must, I presume, be erroneously reported.

†† Former Report, p. 251.

‡‡ In Gehler, vii. 1246.

§§ The unit of measure is not stated.

Boussingault finds a contrary result in the tropics*; but this fact admits of easy explanation, for the height to which they were carried had already passed the region of maximum humidity, above which, no doubt, increased dryness occurs:—

	Metres.	Inches.
Marmato . . .	1426	171·2—154·4 in 2 different years.
Santa Fé de Bogota	2641	100·3

230. Boussingault also notices that, between the tropics, it rains more in the night than in the day, which is the contrary of the case in Europe†.

231. Where M. Osler's self-registering gauge is employed, we have the best means of determining the distribution of rain and the intensity of showers.

232. On the somewhat vague subject of the moon's influence on rain and weather, I must content myself with referring to the recent Memoirs of Arago‡, Brandes§, Baumann||, Eisenlohr¶, Howard**, Kämtz††, Marcet‡‡, and Schubler§§.

VI. Atmospherical Electricity||||.

233. This subject has made scarcely any progress during the last years. The experiments of Schubler are still the best we possess. M. Arago has collected a number of important facts respecting thunder-storms, and drawn conclusions from them, for which we refer to his popular treatise¶¶. Colladon, of Geneva, has proposed to make observations on atmospherical

* *L'Institut*, No. 143.

† See also Schouw on the distribution of Rain.—Edinburgh Philosophical Journal, July, 1836.

‡ *Annuaire*, 1833.

§ *Ueber die Verschiedenen Formen der Wolken, ihre Bildung, die Entstehung des Regens und Hagels, &c.*—Beiträge, p. 285.

|| *Untersuchungen über die Monatliche Perioden in den Veränderungen unserer Atmosphäre.*—Tubingen, 1832.

¶ Poggendorff, xxx. 72; xxxv. 141.

** Proceedings of Royal Society, March, 1840.

†† *Lehrbuch*, iii. 411, &c.

‡‡ *Bibliothèque Universelle*, Fev. 1834.

§§ *Einfluss des Mondes auf die Veränderungen unserer Atmosphäre.* Leipzig, 1830.—Kastner's *Archiv*, v. 169.

|||| See former Report, p. 252, and Mahlmann, p. 209, where the subject is very fully treated. I beg again to disclaim any depreciation of the importance of subjects like the present, over which I may pass very lightly, partly on account of the extent of this report, but chiefly because of the difficulty of establishing any general principles, and of offering any definite suggestions for their advancement.

¶¶ *Annuaire*, 1838. Translated in the Edinburgh Philosophical Journal.

electricity by means of a multiplier, but with what success we have not heard*.

234. On the subject of hail there is a curious paper by Lecoq, founded on observations made in the neighbourhood of Clermont, contained in the *Comptes Rendus*†, and some observations by Beaumont, Buch, and Airy, and on the form of hailstones in the same work‡.

VII. Meteors.

235. This subject has occupied by far too much attention during the last few years to be passed over in silence. A very remarkable shower of falling stars attracting general attention in many parts of the world on the night from the 12th to the 13th November, 1832, recalled the attention of philosophers to the fact, that the *same night* of the year had, on several previous occasions, been similarly distinguished, and especially the 11–12th November, 1799, when they were observed by Humboldt and Bonpland§, as well as in Germany and in Greenland‖.

236. The year 1832 brought a very remarkable occurrence of this kind on the night of the 12–13th November, which was observed over the greater part of Europe, to the middle of Russia, and in Arabia. I was at Geneva at the time, and heard much next day of the appearance, which was such as to strike the most heedless person; but as it occurred very early in the morning, I did not see it. M. Gautier published an account of it¶.

237. This attracted attention to the date of the 12th November, and several confirmations were soon found of the (at least occasional) periodicity of the meteor on that night. In 1831, they had been observed by M. Berard on the coast of Spain**, and also in America††. In 1822 they were seen at Potsdam by M. Klöden; and some other remarkable appearances in November are also mentioned‡‡. But to return to the order of dates.

238. In 1833 was a brilliant apparition, especially in America, always on the 12th November; and these falling stars appeared

* See on this subject the Instructions published by the Royal Society, p. 74; and Becquerel's Work, vol. iv., there referred to; also Kämtz, *Meteorologie*, ii. 389.

† Tom. i. p. 324.

‡ iv. 922. On the subject of Hail, see Fechner's *Repertorium*, iii. 56.

§ *Voyage*, i. 519, quoted by Biot.

‖ Arago, *Annuaire*, 1836, p. 295.

¶ *Bibliothèque Universelle*, li. 189. See also Arago, *Annuaire*, 1836, p. 295. Jameson's Journal, July, 1836. Poggendorff, xxix. 447.

** *Annuaire*, 1836, 295 note. See, too, Silliman, xxx. 386.

†† Silliman's Journal, xxvii. 419.

‡‡ Poggendorff, xxxviii. 551.

to radiate from a point in the heavens near γ Leonis. They were visible from Mexico to Greenland*.

239. In 1834, the phænomenon was less indubitably marked, for it scarcely appears to have been noticed in Europe; and in America, observers were divided as to its amounting to anything unusual; Prof. Olmsted, who was one of the first to suggest the periodicity, maintaining that November, 1834, was marked like the previous years†, and Prof. Bache denying it‡.

240. The year 1835 must be regarded as a very doubtful one for the November meteors. Still it happens, by what must at least be regarded as a singular coincidence, that a very large meteor was seen in France by M. D'Aubenton, which exploded in the department de l'Ain on the night of the 13th November, and probably set fire to a cottage§. Sir John Herschel saw a meteor as large as Venus at the Cape of Good Hope on the 14th, but none on the 13th‖.

241. The apparition of November, 1836, was better marked. The meteors were observed in America¶. M. Arago, by analysing various careful observations in France, has shown that, if not comparable to the showers of 1832 and 1833, they were at least numerically above an average**. They were observed in the Oural in lat. 60°††, and their direction was from the constellation Leo‡‡.

242. It may be doubted whether, in 1837, there was any very decided fall of meteors in November; but I refer below to the recorded observations§§. The weather was not generally very favourable.

243. November, 1838, was not more prolific. Scarcely any notice was taken of the meteors in the *Comptes Rendus*, and the direct testimony of Quetelet, Herschel, and Benzenberg‖‖, show that the phænomenon was, to say the least, not well marked. In America¶¶, it was scarcely, if at all, perceptible.

244. In 1839, I am not aware that any very marked phæ-

* For 1833. See Silliman, xxv. 354; xxvi. 132; xxix. 376. Poggendorff, xxxi. 159; xxxix. 114 (Greenland).

† Silliman, xxix. 167.

‡ Ibid., xxvii. 335; xxviii. 305; xxix. 383. See also Clarke in Silliman, xxx. 369. Poggendorff, xxxiv. 129.

§ *Comptes Rendus*, i. 414.

‖ Ibid., ii. 264.

¶ Silliman, xxx. 386.

** *Comptes Rendus*, iii. 629.

†† *Comptes Rendus*, iv. 524.

‡‡ See also Poggendorff, xxxix. 353; xl. 484.

§§ Olmsted in Silliman, xxxiii. 379; Sir John Herschel, Transactions of the Meteorological Society, i. 77; Arago, *Comptes Rendus*, v. 759; Observations at Edinburgh, Philosophical Magazine, Third Series, xii. 85.

‖‖ *Bulletin de l'Acad. de Bruxelles*, 1838, p. 730.

¶¶ Olmsted in Silliman, xxxv. 368. A brilliant fall was seen at many places on the 6th December. See Herrick in Silliman, xxxv. 361; xxxvi. 355.

nomenon was observed. Under these circumstances, it is plain that we must use the term periodicity, as applied to these meteors, with caution. It is quite possible that some cause may determine their recurrence in November in preference to other seasons, and yet that the repetition may not be annual.

245. It is well known that Chladui*, Brandes†, and Benzenberg‡, have devoted their attention for a long time to these singular meteors; and it is perhaps surprising that we still know so little respecting them. The November periodic meteor has of course given a fresh interest to these; Biot has published an astronomical theory§. Bessel has shown that it is improbable that these meteors ever *ascend*‖. Erman has given a meteorological hypothesis connected with them, which we have before adverted to¶; and Olmsted** and Wartmann†† have likewise written memoirs on the hypothesis of their periodicity.

246. But M. Quetelet, of Brussels, examining the records of this subject, has classified the frequency of meteors at different seasons of the year‡‡; and whilst he finds the middle of November the most prominent period, yet that from the 10th to the 15th August is also well marked. This observation, communicated to the Brussels Academy 3rd December, 1836§§, was confirmed by M. Arago next year‖‖, and, I believe, every subsequent one¶¶. In 1839 they appear to have been very generally observed. M. Quetelet has quoted no less than sixteen years in the present century down to 1837, in which the August meteors have been specially noticed***.

* *Feuermeteore*. See Kämtz, *Meteorologie*, Band iii.

† See an Abstract of his Researches, Silliman, xxviii. 95; and in Quetelet's *Annuaire* for 1837.

‡ He has published a new work, which I have not seen, "*Die Sternschnuppen.*" Hambourg, 1839.

§ *Comptes Rendus*, iii. 663.

‖ Poggendorff, xlvii. 525.

¶ See above (44), and *Comptes Rendus*, x. 21.

** Silliman's Journal, *passim*.

†† *Bibliothèque Universelle*, N. S. ix. 373.

‡‡ *Catalogue des principales Apparitions d'Etoiles filantes. Mém. de l'Acad. de Bruxelles.*

§§ *Bulletin de l'Acad. de Bruxelles*, December, 1836 and 1837, p. 79.

‖‖ *Comptes Rendus*, v. 183. 347; Silliman, xxxiii. 133; *Bulletin de l'Acad. de Bruxelles*, 1838, p. 567.

¶¶ Ibid., vii. 443. tom. ix. *passim*.

*** *Bulletin*, 1837, p. 379. M. Littrow, of Vienna, has observed the meteors of August, and states that their direction of motion is contrary to that of the earth in its orbit, whilst those of November move parallel to it. (*Atti degli Scienzati Italiani*, 1839, p. 19.). I learn, by letters from Sir John Herschel and M. Quetelet, that the meteors of August, 1840, have been observed both here and in America to radiate from a point near γ Persei. Whilst

VIII. Aurora Borealis*.

247. I have little information on this subject to offer in addition to what was formerly given. It is to be regretted, that the system of observation, vigorously commenced by the British Association in 1833, and of which specimens are contained in the report of the Cambridge Meeting, has not been pursued.

IX.—Optical Meteorology.

A. *Colour of the Sky and Clouds.*

248. The blue colour of the sky has, from a very early period, attracted attention. Leonardo da Vinci†, and many succeeding writers, vaguely attributed it to a mixture of light reflected from the matter of the atmosphere with the darkness of the celestial spaces beyond; an opinion which Göthe has revived‡. Muncke§ has asserted that the blueness is a mere ocular deception arising from the structure of the eye, but such a doctrine can hardly now be seriously maintained; and I have elsewhere|| offered an explanation of his fundamental experiment.

249. Newton¶ supposed that the blue of the sky is due to very attenuated vapours producing the first tints of the scale of the colours of thin plates. He further attributes the colours of sunset and of clouds generally, as he had done those of most natural bodies, to the varying thickness of such vesicles**. The latter opinion has been revived and illustrated by Nobili††.

250. Against this theory it may be urged, (1) that the sky appears intensely blue at elevations and under circumstances which forbid us to suppose that vapour can be present at all in a watery or vesicular form (which Newton's statement distinctly supposes), otherwise the hygrometer would attest its existence; (2) that with respect to clouds, were they coloured by the nature of their surfaces as a soap-bubble is, they would present iridescent bands, and they would not partake, as we see

this sheet is passing through the press, I am enabled to add that no decided meteoric appearance has been observed in Nov. 1840 at Paris, or in the West of Europe generally.

* See last Report, p. 254. Mahlmann, p. 230.

† *Traité de la Peinture*, quoted in Gehler's *Wörterbuch*, art. *Atmosphäre*.

‡ *Farbenlehre*, i. 59, quoted by Humboldt.

§ Schweigger's Journal, xxx. 81; and Gehler, *ut supra*.

|| Edinburgh Transactions, xiv. 381.

¶ Optics, book ii., part iii., prop. 7.

** Optics, ibid, prop. 5, end.

†† *Bibliothèque Universelle*, 1830, xliv. 337; and Taylor's Scientific Memoirs, vol. i.

them do, of the general glow so common at sunset which is communicated to all objects indifferently, and which ceases when the sun leaves them in the shade; and (3) that the colours of clouds analysed by a prism by Sir D. Brewster* do not appear to be composed as the colours of thin plates are.

251. Mariotte asserted† that the proper colour of air is blue, just as he considers that of water to be green, and as other bodies have peculiar tints. Bouguer revived this doctrine‡, and added to it the consideration, that if air *reflect* blue light it may be expected to *transmit* the complementary colour as red (as is stated to be the case with sea-water), and hence he explained the fiery colour of the horizontal sun, and the tints of sunset. This opinion has been adopted by Euler§, Leslie||, and many later writers, but especially by Brandes, who, in a most ingenious article in Gehler's Dictionary¶, has maintained its complete adequacy to the explanation of phænomena.

252. This theory must, I think, be considered imperfect rather than erroneous. That the colour of pure air by reflexion is blue, can, I think, hardly be doubted. But that the explanation of the hues of sunset is *incomplete*, can be doubted by no one who is unable to persuade himself, with Brandes, that the difference of intensity on different evenings is only an ocular deception, or depends on the presence of clouds which receive and repeat the colour.

253. Something more is wanting, then, to the explanation, and many acute writers have supposed that some impurity in the air produces, by its absorptive action and variable quantity, the phænomena in question; and several of these authors compare the effect to that of opalescence in turbid fluids, which generally transmit a ruddy beam. Under this head we class Honoratus Fabri**, our countryman Thomas Melvill††, Delaval‡‡, Count Maistre§§, and Sir D. Brewster||||. Of these writers, Count Maistre is the only one who suggests that watery vapour, under peculiar mechanical conditions, may be the source of the variable atmospheric hues, "producing an

* Edinburgh Transactions, xii. 544. Compare *Encyclopædia Britannica*, art. Optics, p. 510.

† *Œuvres*, i. 299. Leide, 1717.

‡ *Traité d'Optique*, p. 365—8.

§ Letters, ii. 507.

|| *Encyclopædia Britannica*, art. Meteorology.

¶ Art. *Abendröthe*, vol. i. p. 4.

** Quoted by Eberhard. Rozier, i. 620.

†† Edinburgh Physical and Literary Essays, p. 81.

‡‡ Manchester Memoirs, First Series, ii. 214.

§§ *Bibliothèque Universelle*, November, 1832.

|||| Edinburgh Transactions, xii. 530.

effect analogous to that of the powder of calcined bones in opaline glass*."

254. I have endeavoured to show† that the colorific property of watery vapour may not merely be gathered from induction, but demonstrated by direct experiment. Having first noticed that high-pressure steam, during a certain stage of condensation, is coloured, and transmits orange-red light, I extended the observation to steam of low pressure. There seems no reason to doubt that the property of vapour, to be coloured in passing from its pure, elastic, colourless state to that commonly called vesicular (such as it appears in clouds, or in issuing from the spout of a kettle), is a general one, and therefore that great masses of vapour at any temperature undergoing condensation must pass through the colorific stage. Now the development of the brightest atmospheric colours is invariably attended with change of temperature. And Forster, without the remotest reference to theory, has recorded that the *sunset glow is contemporaneous with the dew-point temperature*; hence he argues that "some sudden change produced by the *first falling dew* is the cause of the simultaneous change of colour in all the clouds then visible‡". The application of this doctrine to atmospheric colours, as a prognostic of weather, is likewise evident and satisfactory§.

255. *Dry Fogs.*—Of atmospheric colours, which may be considered *unusual*, the blood-red colour of *dry fogs*, which have occurred at various times over a vast extent of country, is amongst the most remarkable. It is hardly possible to believe that they are not due to the accidental intermixture of foreign matter with the atmosphere. Remarkable fogs of this kind

* Edinburgh New Philosophical Journal, vol. xv. Count Maistre explains the colour of water by similar reasoning. He considers it blue for reflected, and yellowish orange for transmitted, light; and the green colour of the sea and some lakes he attributes to diffused particles which reflect a portion of the transmitted tint, and mingle with the blue. This is well confirmed by Davy's observations (*Salmonia*, third edition, p. 317). Arago has very ingeniously applied the same reasoning to the ocean, showing that when calm it must be blue, but when ruffled, the waves, acting the part of prisms, refract to the eye some of the transmitted light from the interior, and it then appears green (*Comptes Rendus*, 23rd July, 1838). Most authors have admitted the intrinsic blue or green colour of pure water, as Newton (Optics, b. i. part ii. prop. 10), Mariotte, and Euler. Humboldt seems doubtful (*Voyage*, 8vo, ii. 133.).

† "On the Colour of Steam under certain circumstances." "On the Colours of the Atmosphere."—Edinburgh Transactions, xiv. 371; Philosophical Magazine, Third Series, xiv. 121, 419; xv. 25; and Poggendorff's *Annalen*.

‡ Researches about Atmospheric Phænomena, third edition, p. 87.

§ Those who wish for fuller details on the history of this part of the subject, will find them in my papers above referred to.

occurred in 1783 and 1831; on both occasions they extended from Europe to America; the former lasted a month, and enveloped the highest Alpine summits*.

256. *Blue Sun.*—At the latter date (1831) the sun's disc was seen of a blue or green colour in the South of Europe and in America. This extraordinary phænomenon we might be disposed to attribute, with M. Arago†, to an ocular deception arising from the intense contrasted orange of the fog, did we not find that it has been repeatedly observed under circumstances to which this explanation would perhaps hardly apply. M. Babinet, a skilful observer, has seen it twice himself‡. He accounts for it by Dr. Young's theory of mixed plates, in which colour is produced by the interference of two pencils of light which have passed through unequal thicknesses of a retarding medium. This he supposes may be the case in the atmosphere by the union of rays "which have passed through vesicles of water or vapour with those which have passed through air only." Now, though M. Babinet has ingeniously imitated the effect by a thin film of mixed air and water placed between two glasses, there is some difficulty in conceiving an *extended* medium like the atmosphere, which should present an analogous constitution §.

257. *Secondary Sunset Tints.*—Many authors have described the appearance of a revival of the sunset glow upon the summits of lofty mountains long after apparent sunset, and ten or fifteen minutes after the tints which accompanied it have disappeared||. The appearance in question was once noticed with extraordinary effect by the writer of this report, in the case of the Jung Frau seen from the profound valley of Lauterbrunnen, from which the sun had so long disappeared that it was almost night below, whilst the upper half of the snowy mountain was illuminated by a delicate but intense red tint, like that of a glowing coal. Prof. de la Rive has offered as an explana-

* *Annuaire*, 1832, p. 244.

† *Annuaire*, p. 249.

‡ *Comptes Rendus*, viii. 306. Sir D. Brewster communicated at Glasgow an account of this phænomenon, observed by Dr. Harvey at Bermuda. See Athenæum, 3rd October, 1840. The appearance referred to occurring on the 10th August, 1831, is evidently part of the same widely-extended appearance quoted by M. Arago in the *Annuaire* for 1832. Dr. Harvey, however, does not appear to have observed the blueness of the *sun's disc*, but only that of objects illuminated by it;—a circumstance, which, had it stood alone, might probably have been accounted for by the doctrine of accidental colours.

§ The phænomenon of the scintillation of the stars has lately engaged the attention of M. Arago, who states (*Comptes Rendus*, 1840) that he has discovered a complete explanation of it founded on the laws of the interference of light.

|| Germ. "*Glühen der Alpen.*" See Brandes in Gehler, art. *Atmosphäre.*

tion of this phænomenon*, that it occurs when the air is extremely clear and highly charged with humidity (as we should expect from (254.)), and that the rays which then reach the mountain have undergone total internal reflexion in the higher and moister strata of the atmosphere.

258. *Aerial Shadows.*—We do not by this refer to shadows of persons thrown on clouds surrounded by coloured glories, of which we will afterwards speak, but of shadows of clouds and other objects projected to a great distance in the air, and which being rendered visible by its imperfect transparency, produce certain remarkable effects of perspective. The diverging rays so often seen proceeding from the sun, when near setting, are of this kind; and the corresponding fact of rays (or clear intervals between the shadows of clouds), which appear to converge to a point diametrically opposite to the sun. This rarer phænomenon we have twice seen; once, combined with a rainbow, to whose centre of course the rays were directed; and lately, from the summit of Goatfell in Arran, whence the rays appeared directed to a point in the sea, and converging from all sides of the circumference. We chiefly mention the circumstance to call attention to a curious and elaborate paper by Professor Necker†, of Geneva, who undertakes to prove that diverging solar rays are sometimes produced by very distant mountains, and that they thus picture forth, to inhabitants of our country, spectral outlines of mountain-chains in another, far removed from direct vision.

259. *Polarization of Sky-light.*—Sir D. Brewster appears to have been the first to remark that the light of the blue sky exhibits traces of polarization‡. I apprehend that it must be difficult to assert that the blue rays are actually so polarized, for the polarization of the white light, with which no doubt the blue is diluted, would produce the effects observed. I do not, however, doubt that such is the case.

260. M. Arago determined the polarizing angle for air to be 45° nearly§, and the maximum polarization of the sky to be 90° from the sun's disc, the polarization being in a plane passing through the eye and the sun. It is a singular fact, and one difficult of explanation, that, proceeding to a greater distance than 90° (in a vertical plane), the polarization diminishes, becomes *zero*, and *reappears in a plane perpendicular to the*

* British Association, Seventh Report, Sections, p. 10. See too a paper by Prof. Necker, of Geneva, Phil. Mag., 3rd series, i. 335.

† *Annales de Chimie*, Fev. Mars, 1839, and *Bibliothèque Universelle*, xxiii. 355.

‡ Treatise on New Philosophical Instruments, p. 350. Edinburgh, 1813.

§ Biot, *Traité de Physique*, iv. 289.

*former**. The distance of the neutral point from the sun varies with atmospheric contingencies. The position of this neutral point seems to have been at first inaccurately reported, for we find English observers searching for it in the sun's neighbourhood, and not in the opposite quarter of the sky†. The *polariscopes* of Arago and Savart, used for detecting the minutest quantities of polarized light, are little known in this country; it is by their aid that the light of the moon is ascertained to be slightly polarized.

261. On the phænomena of *Mirage* we have nothing new to state. The phænomena of Twilight and of Atmospherical Refraction, although connected with Optical Meteorology, we shall also omit.

B. *The Rainbow.*

262. There is no step in the progress of science more interesting than that which calls in the aid of comparatively abstruse principles to explain the slighter outstanding variations between theory and observation, which were overlooked in the first unqualified satisfaction with which the announcement of a simple general principle, harmonizing with every-day experience, is invariably received. Amongst such cases may be reckoned the law of double refraction in crystals with *two* axes, Laplace's correction for the velocity of sound,—and we may now add, the phænomena of the rainbow, so far as these were not included in Newton's general explanation.

263. The diameter of the *primary* rainbow (caused by two refractions with one intermediate reflexion), and of the *secondary* (caused by two refractions and two reflexions), may be most easily found by the formulæ which M. Babinet has lately given ‡ for expressing the radii δ, *directly* in terms of the refractive index of water m, viz.

$$\text{For the primary, } \sin^2\frac{\delta}{2} = \frac{(4-m^2)^3}{27\,m^4}$$

$$\text{For the secondary, } \sin\frac{\delta}{2} = \frac{m^4+18\,m^2-27}{8\,m^3}.$$

* See Peclet, *Traité de Physique*, 4me edit. art. 1448. I am unable to state where M. Arago's original account of these experiments is to be found. Compare Quetelet's Notes to Herschel on Light, French Translation, ii. 554.

† Airy and Chevallier, Philosophical Magazine, N. S., iv. 312, 313. I must add, however, that a very recent communication by M. Babinet to the French Academy of Sciences (*Comptes Rendus*, 19th October, 1840) states the existence of a *second* neutral point, 20° or 30° distant from the sun.

‡ *Comptes Rendus*, iv. 646. The demonstration is given in Peclet, *Traité de Physique*, 4me édit. art. 1489.

Adopting with Newton * the index $m = \frac{4}{3}$, we obtain

For the first . . . . . . $42^\circ\ 2'$
For the second . . . . $50^\circ\ 59'$.

264. The comparison of these theoretical angles with observation is not so easy as might appear, depending (1) on the doubt which ray of the red space we are to consider as the last visible one in the rainbow, and (2) on the gradual shading off depending on the sun's apparent diameter. There is reason to think that the measures of the rainbow require revision; but we would rather place the fate of the theory upon other grounds.

265. The first fact which Newton's theory did not embrace, was the existence of *supernumerary* or *spurious* bows; *within* the Inner, or Primary Rainbow, and *without* the Outer, or Secondary one. These were very accurately described by Langwith in 1722 †,—three internal rings of green and purple (with traces of a fourth) associated with the primary rainbow. The much rarer phænomenon of the supernumerary exterior bows of the secondary rainbow has been noticed by Dicquemare ‡ and Brewster §. The supernumeraries have the same order of colours as the bows to which they belong, *i. e.* those within the Primary have the Red exteriorly, those without the Secondary the Red interiorly.

266. Pemberton ‖ explained these spurious bows by the colours of thin plates; and at a much later period Venturi ¶ attempted to account for them by the deviation of the figure of falling drops from sphericity. Such fallacious endeavours show how cautiously we should receive explanations of such phænomena on the grounds of general plausibility. The true explanation had already been given by Dr. Young, who in pursuing his fertile discovery of interference, pointed out its application to the rainbow in a manner so clear**, that it is surprising how for thirty years, this, one of its happiest adaptations to phænomena, has been so generally overlooked.

267. In the ordinary geometrical theory of the primary rain-

* Optics, book i. part ii. prop. 9.

† Philosophical Transactions, 1723, quoted by Dr. Young. Dr. Young cites Mariotte as the first who mentions supernumerary bows (*Chromatics*, Encyc. Britt.), but without a reference.

‡ Quoted by Young, Lectures, vol. ii. p. 316.

§ Edinburgh Journal of Science, vol. x. p. 163.

‖ Philosophical Transactions, 1723, quoted by Dr. Young.

¶ *Commentari sopra la Storia et le Teorie dell Ottica.* Bologna, 1814. Quoted by Dove and Kämtz (Meteor. iii. 165).

** Phil. Trans. 1804. Read Nov. 24, 1803. Lectures, vol. i. 470; ii. 316.

bow, it is well understood that a limit of deviation, due to two refractions and one reflexion of the sun's light within the drop is a definite and impassible one. The illumination of the bow is produced by the accumulation of rays near the limit of maximum deviation ; an incidence a little greater or a little less than that due to the limit will equally give a smaller deviation ; and as in a shower there are assumed to be drops which shall send rays to the eye in any given direction consistent with the relative position of the observer and the sun, rays more or less approaching to parallelism (therefore more or less densely luminous) will reach the eye from drops placed so as to furnish rays at less angles than that of extreme deviation. Confining our attention to a single colour (the red, for instance, which is the outermost in the primary rainbow), we should expect to find a red bow, quite sharply terminated exteriorly, but shading off gradually, though pretty rapidly, towards the interior. When we recollect, too, that this reflexion within the angle of maximum deviation is derived from rays which have fallen at a smaller as well as at a greater angle of incidence than the critical one, and which therefore emerge rigorously parallel, we are surprised at first sight that the insulation of the colours in the successive arcs should be as great as it appears to be.

268. The doctrines of physical optics, as laid down by Dr. Young, enable us to explain this satisfactorily ; for the very reduplication of the reflected light just alluded to (which a very little reflection will show to be derived from opposite halves of the drop, separated by the position of critical internal reflexion for producing the maximum deviation) reminds us of the fundamental fact of interference, that annihilation as well as increase of light may attend the union of rays proceeding in a common direction, derived from a common source, but which have traversed paths of different lengths. Whilst, then, near the critical angle of reflexion the luminiferous waves necessarily reach the eye in the same, or nearly the same phase, the rays derived from a greater and a less incidence have (though they ultimately coincide in direction) described paths whose difference will soon amount to half an undulation, when their effects will be mutually destructive. Thus by the principle of interference the bow of any colour has its interior boundary far more sharply defined than if such a cause (which is manifestly modified by the size of the drop) had not existed*.

* See Young's original paper, Phil. Trans. 1804, where he estimates the possible breadth of the diffused zone of light, which otherwise would have shaded off from the rainbow, at 25°.

269. Thus, but for interference, we should have had but a feeble and impure rainbow. But further, the same considerations explain the supernumerary arcs: for it is evident, from what has now been stated, that after destruction of light by opposition of phases has been produced, an equal additional retardation of the one ray upon the other will produce concurrence of phase, and double light; hence, as in all similar cases, a series of luminous bands rapidly diminishing in breadth and in intensity will be formed with more or less vividness, depending upon the brilliancy of the reflexion and the separation of the bands (which again depends on the size of the drop). The distance between the true and spurious bow gives the data (upon principles which will be very readily conceived *) upon which the diameter of the drops of rain may be calculated, which Dr. Young finds to be between $\frac{1}{70}$th and $\frac{1}{80}$th of an inch†. By similar principles it is found that the supernumeraries of the secondary bow will be exterior to it and somewhat broader.

270. The darkness of the space between the primary and secondary bows is equally a consequence of the common theory and the corrected one ‡. It is dark compared to the spaces containing the diffused lights (what Dr. Young calls the double lights, or *duplicatures*) corresponding to the respective bows. This darkness was described by Descartes§. The light of the primary and secondary bows‖, and also of the supernumeraries so far as observed¶, is polarized in the place of reflexion.

271. Mr. Airy has recently investigated fully the intensity of the light in the neighbourhood of a caustic formed by reflexion

* Viz. for the observed deviation of the red ray in the spurious bow, find the angles of incidence and reflexion within the drop for the two rays which combine to produce it, and find the difference of the paths of the rays which correspond to this in terms of the radius of the drop. Reduce the difference of paths in water to that in air, and equating it to the length of a wave of red light, find the radius of the drop. Dr. Young has indicated this process in his obscure but able and comprehensive article *Chromatics*, in the *Encyclopædia Britannica*, with which Mr. Potter, who has recently written in support of Dr. Young's views (Camb. Trans. vi. 141), appears not to have been acquainted.

† Philosophical Transactions, 1804, and *Chromatics*.

‡ It is, however, very imperfectly or inaccurately explained in most popular treatises. Mr. Ainger has given a very detailed account of it in the Journal of the Royal Institution (Feb. 1831), in which he has added nothing material to what was shown by Dr. Young; nor has he adverted to the cause of the supernumerary bows.

§ Brandes, art. *Regenbogen*, in Gehler, p. 1324. Kämtz, *Meteorologie*, iii. p. 158. It is very singular that neither of these authors seems to be aware of the true theory of the rainbow, or of Dr. Young's writings on the subject.

‖ First observed by Biot. See *Annales de Chimie*, xxxix. 430.

¶ Arago, *Annales de Chimie*, *ibid.*

and refraction as in the rainbow*. Computing the intensities rigorously on the principles of the undulatory Theory of Light, he arrives by laborious numerical computations at the following results:—

1. The boundary of the caustic is not a mathematical line; but the light shades off with extreme rapidity.

2. The radius of the primary bow does not coincide with the geometrical caustic deduced by the common theory. It lies within it at a distance depending on the size of the drops, and on the consequent separation of the interference fringes.

3. To find the radius of the geometrical bow from observation, "Add to the radius of the brightest observed bow $\frac{11}{24}$ of the distance between it and the first supernumerary bow."

4. Between the primary and the first supernumerary there is a space absolutely dark.

272. As several of these results differ quantitatively from those deducible by the simpler methods of Dr. Young, it is of importance to verify them experimentally. For the reasons already stated (264.), it is difficult to obtain satisfactory comparative measures from the natural rainbow. Much more delicate observations are obtained by an ingenious experiment devised by M. Babinet, of allowing a minute stream of water to flow through an opening $\frac{1}{25}$th of an inch, or less, in diameter, and observing the deviation of rays proceeding from a small luminous body†. In this way Professor Miller, of Cambridge, has confirmed Mr. Airy's result as to the deviation of the principal bow from the geometrical place of the caustic‡.

273. The existence and positions of the supernumerary bows and their dependence on the diameter of the refracting cylinder of fluid (and likewise on its index of refraction), have been shown by M. Babinet himself, who has observed no less than *sixteen* interior, and *nine* exterior supernumeraries, by means of a streamlet of water of the diameter above-mentioned§.

274. With a comparatively large ($\frac{4}{10}$ths of an inch) cylinder of glass he obtained the usual theoretical dimensions of a bow for the appropriate index of refraction. The supernumeraries were excluded by the size of the cylinders; but he obtained bows caused not only by *one* and *two* internal reflexions, but *three* and *four*, up to *seven*. These, the ternary, quaternary, &c. rainbows have been long theoretically known, though rarely, if ever, observed in nature. The ternary rainbow ought to occur

* Camb. Trans. vi. 379. The abstract in the Phil. Mag., Third Series, vol. xii. p. 452, is inaccurate.

† *Comptes Rendus*, iv. 647.

‡ Phil. Mag., Third Series, vol. xiii. p. 10. This experiment was shown to me by Professor Challis.

§ *Comptes Rendus, ut sup.*

about 41° from the sun, but is generally stated * to be too faint to be visible. Two observations by Bergmann are the only recorded ones I have met with †. Kämtz observed a ternary bow amidst the spray of the falls of Schaffhausen ‡.

275. We have said that the appearance of supernumerary bows indicates the presence of rain-drops *below* a certain size, as well as of considerable uniformity of dimension. It is remarkable that Langwith observed, more than a century ago, that "this effect depends upon some property which the drops retain whilst they are in the upper part of the air, but lose as they come lower down and are more mixed with one another." M. Arago seems inclined to suppose, on the authority of d'Abbadie and the officers of the Venus §, that supernumerary bows are rarer in equatorial climates than in ours. It should be recollected, however, that Bouguer saw them in South America with an unusual degree of vividness and separation ||. M. Arago has recommended to the Academy of Sciences of Paris the execution of a good coloured view of the rainbow, as a guide to observers.

C. *Halos* ¶ *and Parhelia.*

276. The apparent complication of the phænomena of halos and parhelia has given rise to a great deal of vague speculation and loose though ingenious theory. Observations of facts have been likewise wanting in precision. On these grounds, we will endeavour very briefly to discuss that part of the subject which seems to have been most successfully dealt with, and endeavour to refer the explanations which have been given, to their proper authors; for so much has been written on the matter that the same thing has been produced as new by various writers at different times.

277. What would first be desirable would be a clear statement of what is to be considered a complete or normal example of the compound display of halos and parhelia. The phænomenon seen by Hevelius, at Danzig, 20th of February, 1661 **, which has generally been considered as a characteristic example, consisted principally of—

* By Young and Babinet.

† *Abhandlungen der Schwedischen Academie für* 1759, p. 234. Quoted by Brandes.

‡ *Lehrbuch*, iii. 160.

§ *Annuaire*, 1840, p. 305.

|| *Mém. de Paris*, 1757, p. 60, quoted by Kämtz.

¶ The halos now spoken of are the great halos of $22\frac{1}{2}°$ and 46° radius, and have no reference to the small halos or coronæ with which they are often confounded, but which have a distinct origin.

** It is figured in almost every work on the subject. See Huyghens's *Op. Reliqua*, ii. 38, and Fraunhofer in Schumacher's *Abhandlungen*, Heft iii.

(1). Three halos round the sun, having Radii of 22½°, 46°, and 90° nearly. The two smaller circles are generally coloured, the *red* being innermost. The circle of 90° is a rare appearance*, and is colourless.

(2). A horizontal circle passing through the sun in which the parhelia or mock suns occur, usually at (or rather a little beyond) the points where the halos intersect the horizontal (or *parhelic*) circle, and sometimes also in the point exactly opposite to the sun (*anthelion*).

(3). Arcs of circles with reversed curvatures, touching the halos of 22½° and 46° at their highest and lowest points. Mock suns sometimes appear also in the halos vertically above the true sun.

278. Even more complex phænomena are occasionally recorded, as that observed at Petersburg, 29th of June, 1790, by Löwitz†. For a history of such appearances we must refer to Brandes's article in Gehler's Dictionary, Kämtz's Meteorology, the article Meteorology in the Encyclopædia Metropolitana (with an excellent plate), Fraunhofer's paper on the subject‡, and to Dr. Young's invaluable catalogue of references§. In the meantime we proceed to the theory of the fundamental appearances.

279. In the 17th century Mariotte referred the halos of 22½° to refraction through triangular prisms of ice. Minute icy spiculæ being conceived to float through the air, or rather to descend slowly through it in all possible directions, a diffused refracted light must be seen, as is actually the case when the air is in this state; but those prisms which chance to be in a position such as to refract the sun's image to the eye in the position of minimum deviation, will (as in the rainbow, where the deviation is a maximum) affect the eye more intensely on account of their parallelism and accumulation. The least deviated rays (the red) will fall upon the eye at the smallest angle with the sun, and consequently will form the smaller ring of the halo‖.

280. Huyghens proposed a different theory¶, which for a time superseded that of Mariotte. He attributed the phænomena to refraction through spherical and cylindrical particles of hail having opake nuclei of determinate magnitudes. But the arbitrary nature of his hypothesis is contradicted by the constancy

* In fact, the observation of Hevelius was unique in this respect until the circle of 90° was recently witnessed by Erman (see Poggendorff's *Annalen*, 1840, xxxix. 255. *note.*).

† Figured by Young (Lectures, i., plate xxix. fig. 433) and by Kämtz.

‡ Schumacher's *Astron. Abhandlungen*, iii. § Lectures, vol. ii.

‖ Mariotte, *Œuvres*, 1686, quoted by Young.

¶ Huyghens, Phil. Trans., 1670, and *Opera Reliqua*, ii. (Young).

of the radii of the principal halos, which indicates a uniformity of cause incompatible with Huyghens's assumption. The theory of Huyghens is alluded to by Newton, though without any express approbation, at the close of his Theory of the Rainbow*; and in another part of his Optics† the principle of refraction through ice-prisms of 58° or 60° is distinctly stated as the probable cause of halos of 22½°, which appears to have been Newton's own view, as he gives a reason for it (the oval form of some halos‡), and does not quote Mariotte.

281. So little reason, then, is there for supporting Huyghens's theory on the ground that it was maintained by Newton, as M. Biot has done§, even since Mariotte's theory has been revived by Young, who published it in the second volume of the Royal Institution Journal||, where he states that he had adopted the principle before he knew of Mariotte's application of it; and he had even inferred from it that the refractive index of ice is less than that of water, a fact then doubted, but afterwards confirmed by Dr. Wollaston¶. M. Babinet has therefore no ground for affirming** that M. Arago was the first to revive Mariotte's explanation.

282. The most obvious facts in support of Mariotte's theory of icy prisms are,

(1). That the imperfect crystals of ice which alone we can obtain, have a tendency to rhombohedral crystallization, amongst the forms of which are three- and six-sided prisms; and the minimum deviation of light through an ice-prism of 60° would give the halo of 22½°.

(2). The *constancy* of the effect gives a probability to a constant cause, such as a crystalline angle.

(3). The fact that halos occur most frequently in cold climates and after a sudden fall of temperature, when the moisture of the air is evidently and palpably deposited in icy spiculæ or hoar frost. In the excellent observations made in the United States, the relation between the sudden fall of the thermometer and the occurrence of halos is very clearly traced††.

* Optics, book i. part ii. prop. 9.

† At the end of the second book.

‡ It is rather singular that the same reason which was urged by Newton in favour of the theory of refraction by ice-prisms, should be stated by Arago (*Annuaire*, 1836, p. 303; 1840, p. 303) as an anomaly which, on that theory, still requires explanation. It is plain that Newton had some theoretical opinion on the subject which he has not explained, and according to which the upper radius of the halo should be shorter than the lower.

§ *Traité de Physique*, iii. 476.

|| See his *Lectures*, ii. 306.

¶ Ibid.

** *Comptes Rendus*, iv. 639.

†† Annual reports made to the legislature by the Regents of the Universities of the State of New York.

(4). The important fact ascertained by M. Arago, that the light of halos is polarized by refraction and not by reflexion *.

283. But other evidences arise from the application of the same principles to the phænomena which accompany the first halo, and many of which Mariotte pointed out so clearly as to supersede much which has since been written on the subject.

284. The halo of 46° may be ascribed to two refractions with the minimum deviation through two successive prisms of 63°, or as Cavendish supposes †, to the refracting angle of 90° formed by perpendicular terminations of the ice-prism. Such terminations, Dr. Young observes, are rather doubtful, and in his later writings ‡ he inclines to the doctrine of successive refraction through two prisms. Fraunhofer § supposes pyramids with angles of 88° to be the cause; and he assigns as an explanation, which appears to him perfectly satisfactory, of Hevelius's great circle of 90°, the limiting angle of *total reflexion* in six-sided prisms, which is 89° 56′. Hence this circle is white.

285. *Parhelia.*—Mariotte accounted for this phænomenon by the preponderance of ice-prisms in a vertical direction (which he attributed to their being heavier at one end,—Dr. Young, more justly, to the resistance of the air ||), which therefore will form a brighter coloured image of the sun when the plane of refraction is horizontal than in any other plane. Mariotte had even the acuteness to see, that as the sun rose above the horizon, the plane of refraction being no longer accurately horizontal in order to reach the eye, the virtual refracting angle of these vertical prisms would necessarily be increased, and the deviation being greater, the parhelia would *stand out* beyond the limit of the halo, a fact remarkably coinciding with experience. Thus an officer of Sir Edward Parry's Expedition ¶, observed parhelia distant 24° 40′ from the sun, the halo being at 22° 30′. The parhelia are coloured, the red edge being nearest to the sun.

286. The *horizontal* or *parhelic circle* is not accounted for by Mariotte, because (he says) he had not an accurate description of it. His commentator, Dr. Young, ascribes the horizon-

* *Bulletin Universel* (Ferussac), 1825, Sci. Math. iii. 304.

† Young, *ut supra.*

‡ See the article *Chromatics* in the Encyclopædia Britannica. But the same doctrine is stated in his earliest papers, to which nothing of any consequence has been added in elucidation of this subject, except M. Arago's important observation of the plane of polarization.

§ Schumacher's *Abhandlungen*, iii. 77.

|| Journal R. Inst. and Lectures, ii. 307 (1807).

¶ Quoted in art. *Meteorology*, Encyclopædia Metropolitana, p. *169.

tal circle to "the reflexion or even the repeated refraction of the vertical facets*", an explanation which seems entirely satisfactory; for though amorphous vertical fibres would produce the same effect (as Fraunhofer showed), yet it is much more natural to ascribe the horizontal circle to the same cause with the parhelia which occur within it, and which are, in fact, merely its most notable points. Young attributes the mock suns occasionally observed at an elongation of about 142° to two refractions and one reflexion in the same ice crystals†.

287. Fraunhofer, in his Memoir already cited‡, ascribes the horizontal circle to the superposition of diffraction-spectra, which produce an excessively elongated image of a body viewed by reflexion from a striated surface, like that of glass smeared with grease, and then cleaned by rubbing it in one direction, when a whitish reflexion will take place perpendicular to the streaks. A similar view has been given more lately by M. Babinet§, who compares the horizontal reflexion to that observed from fibrous crystals, such as topaz and gypsum.

288. *Contact-arches*‖.—The only remaining phænomenon which seems fairly accounted for, is that of inverted arcs of luminous circles touching the halos, usually at their vertical diameter and accompanied by a parhelion, so that Dr. Young describes it as "a bright parhelion immediately over the sun, with an appearance of wings or horns diverging upwards from the parhelion¶." This Dr. Young has ascribed with great ingenuity and probability to very short triangular prisms, which from their flatness fall with their axes and refracting edges in a horizontal position, so that the plane of refraction is vertical. The abundance of such prisms (compared to those which fall obliquely and form the halo) give rise to the vertical parhelia (which Fraunhofer has, I think very unsatisfactorily, explained by diffraction**). Horizontal prisms parallel to the former, lying to the right or left of a vertical plane, passing through the observer and the sun, will evidently refract the solar image in a plane not perpendicular to the axis of the prism (because not vertical), and for which the refracting angle being greater, the solar image (formed always at the angle of minimum deviation,) will appear more elevated as the obliquity of refraction is greater, that is, as we proceed to the right or left from a line vertically above the sun. Dr. Young has confirmed his view by actual calculation††.

* Lectures, i. 444. † Chromatics, sect. ii. ‡ P. 87.
§ *Comptes Rendus; ut sup.* ‖ See art. 277. (3).
¶ Lect. ii. 307. col. i. See the figure of Hevelius's halos, and others.
** Schumacher, *ut supra*, p. 78. †† Lect. ii. 308. col. i.

289. Vertical lines passing *through* the sun and circles containing the sun in their circumference have also been described. The former seem to be independent of the existence of ice crystals; I shall therefore return to them presently. As to the latter, we can only state generally, that from the wonderful complication which the figures of crystallized snow and hoar-frost take, we can conceive circumstances adapted to almost every degree of complication; and such complication may be aptly illustrated by the curious figures which Sir D. Brewster has given of the wonderful variety of reflected figures observed at the surfaces of disintegrated crystals*. The same ingenious philosopher has illustrated the phænomena of halos by observing a distant light through alum crystallized rapidly on a plate of glass†.

290. M. Galle of the Berlin Observatory has lately published an elaborate paper on the subject of halos and parhelia‡, in which he gives a minute account of those observed by himself during nineteen months. Within this time he saw seventy-eight halos of $22\frac{1}{2}°$; of which only two were sensibly elliptical; and he saw no halo of 46°. He afterwards gives at great length a general view of the theory of refraction by ice-prisms.

291. A remarkable parhelic appearance was observed by Lambert at Wetzler, in 1838, in which there were two horizontal circles at greater altitudes than the sun, but *none passing through his disc*. Besides the usual lateral parhelia there were four others at the points of contact and intersection of the halos of $22\frac{1}{2}°$, and 46° with the horizontal circles§.

D. *Coronæ: Glories, &c.*

292. The coloured rings so frequently seen round the sun and moon when thin clouds pass over their discs, are carefully to be distinguished from true halos, as they may easily be, by the following characteristics, which evidently point to a wholly different origin:—

* Edin. Trans., vol. xiv. plate x., &c.

† Edin. Phil. Journal, viii. 394. This experiment, which has probably been oftener quoted than repeated, I have more than once attempted without success.

‡ Poggendorff's *Annalen*, 1840. xxxix. and 241.

§ *L'Institut*, No. 321, Fev. 1840. M. Moigno, who quotes this description from Poggendorff's *Annalen*, claims for M. Babinet the theory of the parhelic circle and vertical parhelia. These are, however, both due to Young; the only addition which, so far as I know, M. Babinet has made, is the very just remark that the horizontal circle will be brighter *beyond* the first halo than within it, because in the latter case the illumination is derived from reflexion only, by the vertical facets; in the former from refraction likewise.

(1). They are much smaller, their radii (when several series of their colours appear at once) being from 1° to 6°.

(2). The radius of any ring is not constant at different times.

(3). The red occupies the *outer* ring, instead of the inner one as in the true halo.

293. These coloured rings have a manifest analogy to those which bear Newton's name; and that great man, in his Optics*, has given an explanation, which, translated into modern language, would express the interference of the light reflected from the different parts of the drop. In June, 1692, he observed three rings or orders of colours round the sun of the diameters of 5° or 6°, 9° 20′ and 12°; on the 19th February, 1662 (so early had he begun to speculate on these subjects), he had observed the two inner coronæ round the moon to have diameters of 3° and 5½°, little more than half the dimensions of the others.

294. The true explanation was unequivocally given by Young in 1802, in his paper "On some cases of the production of colours not hitherto described†," amongst the consequences of the fertile principle of interferences, though in a different way from what Newton had imagined, or Jordan, who had attributed these colours to the inflection of light. Young had practically shown that the interposition of uniform striæ or powder between the eye and a luminous object produces coloured images of that object, depending for their position upon the dimensions of such striæ or powder; and he had theoretically given that beautiful explanation which was afterwards put in a more popular form by Fresnel and Fraunhofer. Yet it is remarkable, that the latter author (Fraunhofer), in describing the experiments on which he grounds the very same explanation of coronæ, never mentions the name of Young‡.

295. The explanation in effect amounts to this,—that on the wave-theory of light, a luminous point is seen only in one direction, because the diverging wave produced propagates from its surface at any moment impulses which, when they reach the eye with any sensible obliquity, have their effect compensated by the opposite displacements caused by the adjacent portions of the wave. By the interposition of particles, opake or of a certain refractive power, and of nearly uniform size, portions of light become sensible in an oblique direction, by the stoppage of the other portions whose different length of path would have caused them to annihilate the action of the

* Book ii. part iv. obs. 13. † Philosophical Transactions, 1802.

‡ *Entstehung der Höfe kleiner, Art.* Schumacher, *Astr. Abhandl.*, iii. 56.

first. The angle of obliquity in which any light will reappear must depend upon the size of the opake particles; consequently, such coloured rings as this cause produces will vary with the size of the interposed globules of water or vapour, and will generally be larger as these are smaller. This was the principle of Dr. Young's *Eriometer* for measuring the diameter of fibres and powders*. Thus Dr. Young has shown†, that a Corona, 8° in diameter, corresponds to the existence of drops (or spherules of any kind) $\frac{1}{2183}$ in diameter.

296. As might be expected, this dimension varies with the season. It appears, from the careful observations and computations of Prof. Kämtz‡, that the diameter of the spherules is least in May, being then ·00054 French inch; and greatest in January, when it is ·00107 inch. This is one of the most certain data relative to the constitution of clouds. There seems no doubt that these are the "Vesicles" observed by Saussure§.

297. The successive orders of colours recur at angular distances, nearly, or exactly, in arithmetical progression from the centre‖.

298. *Glories.*—The well-known phænomenon of coloured rings surrounding the shadow of an observer thrown upon a cloud, has an evident analogy with the preceding one; and up to a certain point, the same explanation may apply. But there are peculiar difficulties connected with this appearance, which seem to be yet imperfectly resolved.

299. Bouguer observed in South America his shadow thrown on a cloud, and surrounded by coloured rings of 5° 20′, 11°, and 17°, and a white ring of 67° in *diameter*¶. Scoresby observed at sea a similar phænomenon on a thin stratum of fog. The rings had *radii* of 1½° or 2°, 4° 45′, 6° 30′, and a whitish circle extending from 36° 50′ to 42°. A larger and still fainter circle was once observed**. Professor Kämtz has seen on the Rigi similar circles of radius 37° 27′ on one occasion, and 42° 10′ on another, which he considers as true rainbows, very faintly tinged with red outside, and with blue within. At the same

* Described in his Introduction to Medical Literature.

† Art. *Chromatics*, Encyc. Britt., Sect. xi.

‡ *Lehrbuch der Meteorologie*, iii. 102. § See above, Art. (218) and *note*.

‖ Young. Compare Herschel on Light, Art. 701. Fraunhofer, quoted by Kämtz, iii. 96. Babinet, *Comptes Rendus*, iv. 643.

¶ *Mémoires de l'Académie des Sciences*, 1744, 4to edit., p. 264. Each man saw only his own shadow; but the reason assigned is not very clear. "Chacun de nous vit son ombre projetée dessus (*i. e.* on the cloud), et ne voyait que la sienne, parceque le nuage n'offroit pas une surface unie."

** Kämtz, iii. 108.

station I have seen a single compound circle, of which the red ring had a diameter of 18°; but when I entered the cloud on the surface of which it had been formed, it contracted to about 10°. In the Jura Mountains I once perceived traces of a faint ring of from 75° to 80° in diameter.*

300. Accompanying the coloured rings, there is an appearance of white light, more intense towards the centre (corresponding to the prolongation of a line drawn through the sun and the eye of the spectator), which would give evidently the brightest illumination in the middle point, but for the shadow of the observer's head, which, however, is wonderfully diminished by the nebulous light.

301. That crystals of ice should have anything to do with these appearances, as conjectured by Bouguer and Scoresby, is altogether incompatible with the circumstances under which other observers have seen them. It is equally impossible to refer these rings to the diffraction of the solar light *falling upon particles of vapour surrounding the observer's head*, as Fraunhofer supposed †, and reflected back to his eye from the surface of the cloud; for I have observed these rings distinctly from a height of *fifteen hundred* feet above the cloudy screen, under a brilliant sky. But the common theory of diffraction of particles *reflecting* as well as *stopping* light, affords a plausible account of some of the phænomena. We have only to suppose the constituent materials of the cloud to be spherules (however composed) of nearly equal size which reflect innumerable images of the sun from their surfaces, backwards to the eye. Some of these must be placed at distances which shall re-inforce each other's effect, and some which shall annihilate that effect; and hence periodic colours will result, as in transmitted light (the case of *coronæ*).

302. This opinion is confirmed (1) by the order of colours being that of diffraction rings (the red outermost); (2) by the arithmetical progression of the diameters observed by Bouguer and Scoresby; (3) by the curious fact noticed by myself, that on immersion in the cloud the rings suddenly shrink in size (due, no doubt, to an increase in the magnitude of the cloudy particles in the interior); (4) from the comparison made by Professor Kämtz, between the diameter of the Corona by

* Haygarth, in the Manchester Memoirs (1st Series, iii.), gives rather an unsatisfactory account of a glory which must have resembled those seen by Bouguer and others. The greatest faint circle at a distance from the smaller ones, is distinctly shown in the bad plate which accompanies the paper.

† Schumacher, *Abhandl.*, iii. 63.

Transmission, and the Corona by Reflexion, the same stratum of cloud forming both; and he obtains in general a satisfactory coincidence*; (5) by the curious observation of M. Babinet†, of similar rings formed round the shadow formed on the minute particles of gunpowder which had been laid out to dry.

303. On the other hand, it is not consistent with what we know of such phænomena, that the third ring (for instance), that having a diameter of 18°, should be seen so vividly, and sometimes to the exclusion of any other (for it is hardly likely that so large a ring should be one of the first or second order). The great rings of 67° to 84° in diameter, can scarcely be thus explained.

304. Dr. Young seems to have felt the full difficulty of the subject of reflected glories; and he has unfortunately expressed himself very obscurely upon it. In his earlier writings‡, he contented himself with referring them to the colours of thin plates; but afterwards he seems to have hesitated whether to consider them as modifications of the corona (by diffraction), or of the rainbow. In his article, "Chromatics §," he has given a singularly perplexed theory, which we have read over many times without clearly understanding; the reasoning, however, appears to be this:—Supposing a cloud to be formed of drops of water, light, *four times* reflected within such drops, will furnish rays which will unite in the same phase from both sides of the drop, at a point diametrically opposite to the sun, whilst rays (also four times reflected) ultimately coinciding in direction, and which have undergone reflexion at smaller and greater angles, will unite in different phases, the retardation being nearly as the angular distance from the central point. It is to these supernumerary bows of the fourth order, that he appears to attribute the *inner* circles, whose diameters were, in the observation of Bouguer, 6°, 11°, and 17°.

305. Having found the size of the drops which would give, by diffraction, rings of this description ||, he proceeds to find the distribution of the colours of a primary rainbow formed by such excessively minute drops (less than $\frac{1}{4000}$ inch). He assigns to the first *supernumerary* red bow a radius of 24°, of which, however, he makes no use. He then observes, that owing to the minute size of the drops, the shading off of the primary colours is very slow on the concave side, so that the red will sensibly occupy a breadth of $7\frac{1}{3}$°, the violet of $5\frac{1}{2}$°; and as the red and

* *Meteorologie*, iii. 111. † *Comptes Rendus*, iv. 645.

‡ Lectures, ii. p. 645. col. i. § *Encyc. Britt.*, seventh edit., p. 638. col. i.

|| Computed, however, for a radius of 5° for the first ring; whereas, in Bouguer's observation, the *diameter* was 5° 20′.

violet arcs are already 2° apart, they will overlap, and form a whitish ring, whose radius will be that of the red ring of the rainbow, or 42°, diminished by $7\frac{1}{3}$°, leaving about 35° for the radius of the whitish ring, agreeing sufficiently well with observation.

306. I apprehend, however, that there are many difficulties in this view of the subject. That light, four times reflected, should have intensity enough to produce three or more coronæ, seems incredible. Again, the ring of 37° to 42° radius, observed by Kämtz and Scoresby, with faint colours, seems to be the rainbow itself, not the superposition of its faded colours, for Dr. Young very obscurely hints* as to the non-appearance of the *real* bow. The reason of its variable magnitude and faint colour is quite sufficiently explained by Mr. Airy's investigation (271.), in which the deviation of the maximum of intensity from the geometrical caustic is shown to depend upon the size of the drops, and that diminution of size *diminishes* the radius of the bow, and likewise the sharpness of its definition, though in every case (as it seems to us) the maximum next the caustic must be most intense, and therefore the true bow can never vanish so long as any of its subordinate features remain, which Dr. Young seems to have thought possible. Finally, Dr. Young, in another section of the paper so often referred to†, adopts the theory of diffraction as producing the lesser glories, and calculates the size of the drops on that hypothesis, which size is double that obtained on the other.

307. Had not this discussion been already extended further than persons more interested in meteorology than in physical optics may think suitable, I should have dwelt at some length upon certain curious phænomena of shadows with luminous borders, and certain vertical trains of light seen in connexion with them, which seem not to have received the attention which their theoretical importance demands. I will state very briefly what may serve to instigate further inquiry.

308. Standing on the tower of Carisbrook Castle with a friend one calm hazy summer evening near sunset, I perceived glorified shadows as from the Rigi, but without colours. So intense was the concentration of rays opposite the sun, that the shadow of the head of the observer was almost obliterated by the intensity of the light which seemed to emanate from it. The shadow of the body was *fringed* all round by a luminous but *colourless* border. The shadow of another person standing a short way

* Chromatics, p. 635, col. i.; p. 638, col. i.

† Chromatics, Sect. xi.

off presented to the first observer nothing peculiar. The luminous haze extended but a short way right and left, but in a vertical direction it extended through a very considerable angle, producing the very singular effect of a train of hazy light. The same effects I have seen less perfectly in other localities, but generally towards sunset, and only when a considerable space intervened between the observer and his shadow.

309. Similar phænomena have been described by various observers, and variously accounted for*. The vertical train of light which occasionally accompanies halos, has been explained by the reflexion from the bases of vertical crystals†; but as it is seen to occur in circumstances such as those mentioned in the last paragraph, it must evidently be independent of the existence of ice in the air. Fraunhofer has endeavoured to explain it on principles of diffraction‡, and I conceive that it is most likely to be explained on some such principle, taking into account the abrupt variations of temperature which often take place near the ground towards sunset, and which produce strata of air very variously charged with moisture in various degrees of condensation, horizontally disposed, and partial reflexion in which would undoubtedly tend to produce a diffuse vertical image, such as we see on water slightly rippled, when looking across the rippled surface. The main cause, however, of this expanded vertical image appears to be, that by looking very obliquely through a thin stratum of cloudy particles, their apparent distances will be diminished by the obliquity, and their interstices in the same proportion. Diffraction bands will, therefore, expand in the direction in which the particles are apparently compressed. I have found that such phænomena are accurately reproduced by suffering soap-suds to dry upon a plate of glass, and then looking at a flame *obliquely* through it: when viewed *perpendicularly* neither colour nor diffused light appears in one direction more than another.

310. The occurrence of the anthelion itself, or luminous point opposite the sun, is not of so easy explanation as some writers seem to consider it; and until it is fully understood, we can hardly hope to explain all its modifications. The glory

* See the observations of Hevelius, Derham and Young, quoted in Young's Lectures, ii. 303, as to the vertical train of light; more lately by Mr. Christie, British Association, 7th Report, Sections, p.15. [Mr. Christie's original communication to the Meeting at Cambridge in 1833, contained in a letter to me, appears to have fallen aside, and is neither published nor in my possession.]

† First by Young, also by Babinet (*Comptes Rendus*, iv. 640), Galle (Pogg. xxxix. 256), and others.

‡ Schumacher, *Abhandl.*, iii. 82.

observed round the head on dewy grass * is evidently referrible to the reflexion from spherical drops at no great distance from one another. The peculiar luminous fringes observed round the *whole* shadow (308.), I have assured myself by many trials to arise from no optical deception. There is a space close to the shadow, and following its boundary, more luminous than the fully enlightened space beyond,—a fact which it seems not easy to explain. It appears to have no reference to the nature of the body (as, whether it is bedewed or not) which yields the shadow; nor is it altogether dependent on the body which acts as the recipient screen, but it depends chiefly, I apprehend, on the condition of the strata of air very near the ground. We must consider it, I suppose, as an effect of diffraction, such as would, in point of fact, be seen where the shadow of a body is thrown upon a screen by a single radiant point at a certain distance; in this case, however, it is not the smallness of the luminous body, but the cluster of minute globules which reflect small images of the sun that are the cause of the diffraction; the effect being to produce a luminous band, succeeded by a darker one whose contrast renders it more visible. The effect is no doubt enhanced by the indeterminateness of the surface which reflects these little images. The shadow is seen through the whole depth of the nearly invisible cloud, and the bounding surface of light and shade will be most prominently seen when the eye is in a position to follow its course in the interior of the mist.

311. The phænomenon described by Professor Necker†, of the intense illumination of shrubs and trees forming the horizon behind which the sun has just set, is, I conceive, a precisely parallel fact; and M. Babinet ‡ has explained it in a similar manner. But there is still something in this as an optical phænomenon which seems to me to require further investigation.

312. It should not be forgotten, with reference to the phænomena of clouds, that they have been treated by Young and others on the hypothesis of their being composed of spherical drops of water. Bouguer, Kämtz and Fraunhofer, maintain their vesicular structure; and the last-named author has in his Memoir, so often cited, considered minutely the course of a ray of light through a spherical watery shell. The great modification which the common rainbow undergoes in a cloud, and the rarity of its

* Garthe, *Abhandlung über den Heiligenschein:* quoted by Kämtz, iii. 106. and other authorities there mentioned.

† Philosophical Magazine, Third Series, i. 332, where two diagrams represent the fact very well, as I remember to have seen it under Professor Necker's directions.

‡ *Comptes Rendus*, iv. 644.

occurrence, seems, to say the least, to give some plausibility to the latter opinion.

X. Suggestions.

313. In conclusion of this report, I propose to offer a few suggestions more definite than I have yet given for the advancement of meteorological science. I have glanced at various questions which require elucidation, and which fall within the scope of science in its present state; but a more systematic recapitulation of some of these will place them more intelligibly before the reader.

314. It has long been matter of regret, that the labour which every one knows is spent on meteorological inquiries, should be so ill-directed; but this it is easier to regret than to remedy. It is discouraging to be obliged to declare that meteorological observations, to be of any value, are not so easy as is commonly supposed, and that not only perseverance but intelligence is generally speaking necessary to make such observations as are useful to science. Many registers, however well kept and organized, are *redundant*; many would be useful were the results reduced and corrected; many may have a *local* value, though they do not greatly advance the general progress of science.

315. For the sake of precision I will combine what I have to say under three heads, (1) On Public Observatories, (2) On Private Sedentary Observations, (3) Suggestions to Travellers.

A. *Public Observatories.*

316. It is of little use complaining of the past neglect of meteorological observations in astronomical observatories. Some attempt is now being made to combine with them a system of meteorological observation, or what is better, to institute magnetical, meteorological, and generally, physical observatories. The vast sums of money which have been spent in *doing over again* what has been better done elsewhere in determining astronomical data, might have almost created new sciences of observation.

317. The meteorological observations at Paris deserve particular notice, as having been conducted upon a simple and regular system, for a considerable series of years. The barometer and thermometer (which, I believe, are kept in good order) are registered four times a day—at 9 A.M., Noon, 3 P.M., 9 P.M., hours evidently selected for the barometic oscillation*. At Brussels the barometer, thermometer, hair hygrometer, wind, and

* Published in the *Annales de Chimie* and *Comptes Rendus*.

state of sky, are registered at 9, Noon, 4, and 9*. At Marseilles a very elaborate register is kept every three hours (I believe) of the day and night, under the watchful superintendence of M. Valz †. At St. Petersburg and other stations of the Russian empire, meteorological and magnetical observations are made eight times a day—viz. at 8, 10 A.M., Noon, 2, 4, 6, 8, 10 P.M.‡

318. Observations are regularly made at the Milanese Observatory, Palazzo Brera, at 0, 3, 6, 9, 12, 18, 21 hours astronomical time, and are published in the *Biblioteca Italiana.* We learn from an article in the *Bibliothèque Universelle*§, that extensive meteorological observations by Sig. Colla, at Parma, are published, under the title of *Giornale Astronomico.* Farther, it appears, that at the late meeting at Pisa, it was agreed, on the motion of Sig. Antinori, to concert measures for contemporaneous and comparable observations throughout Italy‖.

319. The observations conducted at the various academies of the State of New York, and published annually by the legislature, are still continued on a uniform plan, and must be productive of considerable benefit to science. Near the equator, at Trevandrum, in the East Indies, an admirable meteorological register is kept, under the direction of Mr. Caldecott, astronomer to the Rajah of Travancore. During his recent stay in this country, Mr. Caldecott has made arrangements for extending considerably the range of his experiments and observations.

320. The observatories fitted out under the direction of the British Government and East India Company, combine meteorological with magnetic observations every two hours of the day and night¶. It is matter of regret (though it is to be hoped the regret is a temporary one) that whilst these admirable means of observation have been sent to both hemispheres, and to the Antipodes, none have been established *at home***. I am not aware that there is a meteorological register which can be called *authentic* (in respect of the three following qualifications) conducted in any part of the British Islands.

321. The special objects of public observatories would seem to be—

* Published in 4to by M. Quetelet.

† Unfortunately it is not published.

‡ Published under the direction of M. Kupffer.

§ For August 1840.

‖ *Atti degli Scienzati Italiani,* p. 30. Sig. Cacciatore's observations have been already referred to (11).

¶ Forms of Register are prepared by the Royal Society.

** Since this was written I am glad to learn from Mr. Airy that arrangements have been made, by which an authentic Meteorological Register will be combined with the Astronomical and Magnetical Observations at Greenwich.

(1). To furnish standards of comparison;
(2). To establish the laws of phænomena;
(3). To fix *secular*, or normal data.

The second of these determinations may be made without the first and third, and conversely; just as in magnetism one set of instruments serve to measure *variations* of elements, which yet are incapable of establishing the fundamental values of the elements themselves.

322. In respect to the *First* point, the instruments must not only be *originally* good, but they must be preserved in constant repair,—a matter requiring perpetual revision in the case of meteorology. Access, under due regulation, should be permitted to instrument makers and observers to have their instruments compared with the standards*. That the instruments be *absolutely* as well as *relatively* correct, is evidently essential to the determination of the mean pressure at the level of the sea†, the actual state of climate with respect to temperature, &c.

323. *Secondly.*—The laws of phænomena can usually be only made out by extended and minute observation, incompatible, generally speaking, with private research. Laws of a certain degree of generality have commonly a pretty wide domination, even in a science apparently so capricious as meteorology. The instance we have mentioned of the "homonymous hours" (37.), representing the mean temperature of the day, is one of the kind: the constancy of the interval between the hours of mean temperature is another: the mean of diurnal extremes being *nearly* the mean temperature of the day is a third: the nearly coincident hours of diurnal barometric variation is another:—these, and such laws deduced from sufficient data, clear the way for individual exertion, and indeed form the only basis for really useful efforts of the kind. A very small number of observatories (comparatively), perhaps three or four in the extent of the British islands, would be sufficient to supply these important data. The observations must be made every two hours at least, for with less than this the diurnal curve could not be properly drawn. But such laborious observations would not require to be indefinitely continued. Once place the meteorological observations on a proper footing, by ten, or perhaps twenty years' observation of this kind, and the great difficulty is overcome: there is not a chance of *secular* changes sensibly affecting these laws; once established, they are like the laws of the solar system.

* As is done, for instance, at Paris.

† The specific gravity of the mercury should be actually ascertained, and the pressure might be stated in the corresponding height of a column of distilled water at a fixed temperature.

324. Directions would thus be obtained for prosecuting, under the most favourable circumstances, and at the least possible expense of labour, all inquiries as to *local* climate in observatories of the second class, and by private individuals. In such observatories, observations might be made twice or thrice a-day, and some even seldomer. The regular observations at public observatories should include the following:—

Thermometer, barometer and moistened bulb hygrometer, *at least* every second hour.

Wind may be registered by Whewell's and Osler's gauges.

The state of the sky may be frequently noted.

Rain by Osler's gauge; other rain-gauges at three vertical stations.

Temperature of the earth from the *surface* down to twenty-four French feet. The shorter thermometers must be observed at different hours of the day; the longest once a week.

Temperature of the earth at a considerable depth in caverns, wells, or Artesian bores. The thermometers (generally) should have their zero verified from time to time (twice a year).

Solar radiation by the actinometer.

Nocturnal radiation.

Atmospheric electricity and the aurora borealis, with corresponding magnetic observations.

Falling stars, especially in August and November. Other occasional phænomena, of course, will be recorded.

Experiments, by means of balloons, on the decrement of temperature above the soil.

325. It would not be too much to expect that the directors of the first class of observatories should be capable of forming a judgement on the great cosmical questions of meteorology (adverted to in the section of this report on terrestrial temperature,) and of uniting theoretical and practical knowledge to the important end of obtaining tangible and useful solutions of these great problems. For this purpose, it would be necessary not only to institute *observations*, but *experiments*; and, by the trial of many independent plans, to estimate the confidence due to the various methods in so delicate a research. By ascertaining exactly what *data* may be obtained *à posteriori*, a definite problem may then be given to mathematicians to resolve; and we shall then know, and not till then, what investigations are to be regarded as merely speculative, and what of any substantive value.

326. *Thirdly*.—The laws of phænomena being known by such a limited course of elaborate experiment as has been recom-

mended, the next business connected with a public observatory is to furnish the *secular constants* of meteorology, such as the mean annual temperature, the mean annual pressure at the level of the sea, the limits of variation of these, the mean elasticity of vapour, the mean and total quantity of sunshine, the mean direction and integral quantity of wind, and similar facts, *for a given place at a given time*. These observations are of a less elaborate kind than the preceding; but the fate of all *volunteer experiments* shows, that to determine such quantities with minute precision, is incompatible with any but an official system of registration, which shall be conducted for very many years on exactly the *same system*, with instruments of the *same kind*, with unremitting attention not only to the *fidelity of the observations*, but to the *perfect repair and comparability of the instruments*. Even should such a system not be started on the very best possible plan, it is better that it should continue uniform, than undergo perpetual change. If the hours or locality be not the best possible, the diurnal laws being known, the result of any hour may be converted into a *mean* result; and as to locality, it is much more important to preserve the consistency of results, than to avoid *trifling* disadvantages.

327. We have seen that it requires *very many* years' observations to ascertain the mean climateric state of any point of the earth's surface. In this country, for no one such point probably is it accurately known. Let the instruments be the simplest, but the best; the observations, however few, perfectly regular; and we have a certainty that we are laying up valuable facts at least for another generation, if not for the present one.

328. Instead of labouring to collect a multiplicity of imperfect registers, let us begin by laying the foundation of a rational and accurate science. If we can but determine accurately the secular elements of pressure and temperature at a hundred well-chosen points of the earth's surface, we shall do more than has ever yet been done to draw a proper system of isothermal and isobarometric lines, which shall hand down to posterity the actual mean condition of our globe.

329. Observations must not only be made, but they must be wholly reduced and printed, like the astronomical observations conducted by Mr. Airy*. They must be ready to be applied to the purposes of science, and synoptic tables of results widely distributed. In the deduction of Laws from Results, much useless labour may be spared (and the remark is especially applicable to private observers), by employing graphical projections

* For this purpose excellent printed forms have been supplied to the Antarctic expedition.

instead of elaborate formulæ of interpolation, a method which, however valuable in itself, has been carried to excess by the German meteorologists; and the immense labour they have spent in computing arbitrary constants might, in many cases, have been better bestowed. Anything, however, is better than no reduction at all. The engraving of such charts is well worth doing; they often afford a check upon the accuracy of the observation, the value of the method, and the consistency of the results, which no other mode of exhibition can possibly do.

330. I would notice the projection of observations on subterranean temperature (96), as a signal instance of all the advantages which I have mentioned. Where several simultaneous but independent observations are made, the comparison, by projection, gives a *moral certainty* of the fidelity of the observations, whilst the coincidence of one year's observations with another demonstrates the confidence due to the method of investigation even more satisfactorily than the coincidence of final results. Even in point of *accuracy*, the maxima and minima cannot be so well determined by a parabolic interpolation (as M. Quetelet has done), because the temperature-curves invariably *rise faster than they fall*; consequently, the osculating parabola has not its axis vertical, but inclined to the left upwards; and if a series of circular functions be used to express the observations, the computation becomes very laborious, and perhaps the result is not more accurate than may be obtained in a few minutes in the following way.—A thin stiff wire may, by a little practice, be adapted so as to follow, in a remarkable manner, the sinuosities of the temperature-curves: by changing its form by pinching, then bending it elastically, and varying the inclination of its symmetric axis with the vertical, it is easy to lay it so over the curve*, as to satisfy the eye that the inequalities on each side compensate one another.

331. Until national observatories shall be formed, it seems of great consequence that the Plymouth Hourly Observations, made at the expense of the Association, should by no means be discontinued; that the results, amply reduced, perhaps the detailed observations, should be printed at their expense; and most particularly, that the condition of the instruments shall be from time to time verified with the utmost care, in order to render these determinations *positively* as well as *relatively* accurate, for which I do not know whether there is at present any sufficient security.

* Or *polygon*; for in all cases, the *actual points of observation* should be joined by straight lines. This suggestion I owe to Mr. Babbage, and I have found it attended with great advantage.

B. *Sedentary Observations.*

332. Private individuals, fond of science, would find the establishment of such systematic observatories as we have recommended, to add great importance as well as interest to their labours.

333. Their business would then be like that of detailed surveying after the great net-work of triangulation has been completed. The *local* meteorology of a country is often of great practical as well as scientific importance, and the immense difference of climate frequently experienced within a few miles, whilst it shows the embarrassing effect of local causes, and the danger of drawing general conclusions from insulated or imperfect registers, is itself a curious subject of research.

334. Ordinary thermometrical and barometrical registers may be continued, as has been usual, with additional attention to the construction and repair of instruments, the choice of situation, and the choice of hours. In respect of the latter, 9 A.M. and 9 P.M. are very convenient and fitting hours for thermometric observations, to which may be added 3 or 4 P.M. for the sake of the barometric oscillation. But it is one advantage of systematic observation, such as was recommended in the last section, that it will render available observations made elsewhere at any hour or hours by a general principle of reduction to the mean*. Self-registering instruments (thermometers, rain-gauges, anemometers, and the like) are well adapted for private observation from the little superintendence they require.

335. I would, however, particularly urge the propriety of not confining individual efforts to the mere multiplication of simple registers. The same expenditure of time and money is applicable to much more interesting purposes. Special series of observations and experiments on one or more subjects, such as the following, would be of very great interest indeed:—

1. The temperature of the soil at small depths. If the difficulty of procuring long thermometers be an objection, water-bottles may be lowered to different depths *in separate tubes of wood* sunk in a well, which is then filled up with earth or sand, and the temperature may be noted by a common thermometer on pulling them up, the opening of the tubes being well stuffed with hay or wool†. (98.)

* As was clearly pointed out by Sir D. Brewster, in discussing the Leith hourly observations. It must be remembered that such reductions are correct only within the limits of the region or climate for which they have been ascertained.

† A not unimportant modification of these experiments might be made by covering a certain space of the surface of the soil in which the thermometers were sunk, with a composition of *ascertained* radiating and absorptive power.

2. Temperature of mines, galleries, deep wells, overflowing or Artesian wells, rivers at various distances from their source and from glaciers; the sea and lakes at different depths and seasons.
3. Modifications of temperature, + or − *immediately* above the surface of the soil at different hours and seasons. (60.)
4. Decrement of temperature at different heights, and the modification of the annual and diurnal curves due to elevation. (51, 57.)
5. A comparison of the different instruments for measuring solar radiation—Leslie's, Cumming's, Herschel's, Pouillet's. (61, &c.)
6. Observations on nocturnal radiation in different states of the atmosphere, and towards different regions of the heavens (at the same angular elevation); comparison of the ethrioscope (especially the effect of metallic reflectors in increasing cold, questioned by Pouillet); Pouillet's actinometer; the thermo-multiplier. (79, 80, 114.)
7. The ascertainment, by barometric measurement, of the elevation of a number of marked points in the neighbourhood of the observer's residence. A combination of such local results would give the general configuration of a country. The levelling (by the barometer) of the course of rivers, and a few of the most elevated points of the intervening mountain-chains, is most useful*.
8. The relation of the boiling points of fluids, especially water and alcohol, to the barometer, and the supposed anomalies mentioned by Hugi. (163.)
9. The curious anomalies in barometric measurements depending on the difference of temperature of the two stations (Lenz and Galle), and perhaps on the direction of the wind. (159.) This is an important, and, in a favourable situation, not a difficult inquiry†.
10. Further comparisons of the dew-point and moist-bulb hygrometer are not necessary. But careful observations with the latter are highly desirable under all possible circumstances. The curves of annual and daily dryness ought to be investigated, and the indications of the instrument reduced, *not by the computation of the corresponding dew-point*, but by ascertaining (from Apjohn's for-

* See M. Guerin's very interesting *Mesures Barométriques dans les Alpes Françaises*, Avignon, 1829. An excellent specimen of what is here intended is to be found in the Comte de Raffetot's barometric measurements in the valley of Baréges. See Edinburgh Philosophical Journal, January, 1837.

† Ramond's *Mémoires sur la Formule Barométrique* cited in the former Report may be consulted with advantage on this subject.

mula, (175, 180)), the *absolute* and *relative* dryness of the air, *i.e.* the tension of vapour and the ratio to saturation. Experiments would still be desirable to ascertain the effect of a current of air in modifying the indications of the moistened thermometer.

11. To pursue experiments on rain-gauges at three stations vertically above one another, (221) combined with hygrometric observations.
12. To deduce from phænomena proofs of the *revolving* or *radiating* character of storms, or of the existence of both kinds*. (212, &c.)
13. To multiply observations upon meteors, especially in August and November. For this purpose, nothing more is requisite than the combination of several intelligent observers, who should select particular portions of the heavens for observation, having acquired, by the aid of a globe or planisphere a sufficient knowledge of the constellations, and who, being each provided with chronometers, should note, (1) the time of appearance; (2) the duration of the meteor; (3) its magnitude and physical peculiarities; (4) its direction and velocity of motion.
14. From what has been said on the subject of atmospheric electricity, it will appear that almost everything remains to be done on that subject; he who proposes to enter on the field must be prepared to cope with the difficulties of *original* investigation.
15. Auroral phænomena. The division of them into classes (if possible), of which probably the height, nature, and magnetic effects may be very different.
16. Many of the departments of optical meteorology are well fitted for Sedentary Observation. See the particulars specified in the next section.

C. *Travelling Observations.*

336. A traveller is placed in circumstances so eminently favourable for arriving at just conclusions in meteorology and other similarly-conditioned sciences, that he cannot be too frequently reminded of the responsibility which attaches to his situation. All men who have cultivated the valuable art of viewing intelligently what passes around them, may arrive at important deductions from the observations of the most monotonous and most

* Observations of great value may be very simply made by noting the periods of sudden rise of wind, and especially *the times when its direction changes most rapidly*, and the nature of the change. Barometrical observations add to the value of these recorded facts.

sedentary life; but he whose choice or opportunity carries him through many climates and varying circumstances, cannot too zealously watch the occasion of discovering processes which only a happy accident may reveal, and of profiting by the comparison and contrast of phænomena. Every one knows how indolence and indifference steal upon the mind long habituated to a daily-shifting scene, and how apt opportunities are to be lost through weariness or inattention. The traveller would do well, therefore, to entertain some preliminary considerations as to the sort of observation suited to his peculiar position. Systematic observations are, to a great extent, beyond his reach; and regular meteorological journals, kept from day to day under continually varying circumstances, are of much less value than those made in one spot, so that such registers may very generally be abandoned, unless in the case of visiting peculiar or little-known climates, where any sort of approximation to systematic observation is valuable.

337. There are, however, certain phænomena which afford such definite conclusions within the range of a few or even of single observations, as ought especially to engage the traveller's attention; such, for instance, as

1. The temperature of the superficial soil between the tropics, which, as already stated (128, *note*), is generally constant at one foot deep, and represents the annual mean. Intimately connected with this is the important general question whether the superficial earth temperature coincides generally with that of the air, which is yet undecided.
2. The temperature of springs, deep wells, and mines. (117, &c.) The elevation of these above the sea should be determined barometrically or otherwise. Where several springs rise near one another, the temperature of *several* should be recorded. It does not by any means follow, that the largest springs *always* give the best results.
3. Particular attention should be paid to those springs which appear to have a temperature above or below that of the air at the place. In the case of very hot springs it is very interesting to repeat the observation with the same thermometer or instruments which have been compared, in different seasons and years*. (131.)

* Having been requested some years ago to draw up instructions for observing springs, I may, in the hope of attracting additional attention to the subject, introduce them here, not having been elsewhere published.

HINTS FOR OBSERVATIONS OF THE TEMPERATURE OF HOT SPRINGS.

The thermometer used in fixing the temperatures should be originally good, and should besides have its freezing point verified occasionally by plunging it in melting snow. Fractions of degrees should be estimated at least to one-fourth,

4. Meteorological *extremes* have always a certain interest which makes them worthy of preservation, whether they be

if practicable, to one-tenth. If possible one person should note the results at the instant that the other observes, and to avoid errors the observers should then change places. The stem of the thermometer should be immersed in the water, so that the whole mercurial column may be of the same temperature; it should be kept there until the reading becomes quite stationary, and the reading made whilst so immersed.

Hot springs are either uninclosed, or applied to the supply of baths, &c. In the former case great care must be taken in marking distinctly the locality, as springs often occur so near to one another that confusion readily arises: the *bearings* of any permanent objects near should be given, and the *popular* name of the spring, if it have one. If the spring be collected (as is usually the case) from a number of imperceptible sources, the fact should be mentioned and the hottest part taken. In the case of the supply of baths, too great care in reaching the *real* sources cannot be enjoined. The servants of the baths are often ignorant of the true springs, and are unable or unwilling (because they are difficult of access) to point them out. When the real source cannot be reached (from being underground or built up) the nearest bath cock should be tried, having been first opened for some time, and the observer should record the number of the cock, its distance from the spring, and the nature of the conduit, as well as give an eye-sketch of their relative positions. Where the water is stopped in its passage by reservoirs, these should be especially noticed, as they render the observation of temperature of little value. Often the spring rises over a great extent of surface into a large *piscina* or public bath. In this case the observation is generally unsatisfactory, but the temperature of different points of the basin should be ascertained and the hottest recorded. If gas rises it should be ascertained whether its temperature differs from that of the water. The traveller should repeat his experiment on different days and at different hours, and at as great an interval of time as his stay permits. As many springs as possible (of those which are *really independent*) should be observed, and to prevent mistakes as to the independence and purity of the springs (for those more esteemed are often mixed with others of inferior quality) the best authority (usually the resident physician) should at once be consulted. With a view to comparison with former observers, changes in the management of the reservoirs, &c., should be inquired for, and their date noticed.

No ordinary traveller can undertake an analysis of mineral water, but if the spring be employed medicinally he may probably obtain some information from the resident physician or druggist, which should be preserved (with the authority). He may further, after a little experience, judge (by taste and smell) to what class of springs it is referible, as sulphureous, alkaline, saline, chalybeate or acidulous. The easier experiments which he might further make would relate to the specific gravity of the water, and to the nature of the gas evolved, which is a very important question. There are cases in which it might be desirable to preserve, well corked, a portion of the water for analysis, but such are comparatively rare.

Historical and other information may often be got from physicians and intelligent proprietors of baths. Such persons might sometimes be induced to undertake observations every week or month on the precise variations of temperature to which a spring is subject. Almost any thermometer would suffice for this purpose, as only small variations are wanted, and the *absolute* error might be found by comparison with the traveller's standard. But in all cases *the authority for every statement not directly verified by the traveller himself ought to be distinctly given.*

of atmospheric temperature, solar radiation, pressure, humidity, fall of rain, force of wind, or electric tension.

5. Daily observations of the barometer are valuable, especially in tropical regions, because there the calculation of heights may at once be completely made without corresponding observations. By these means a traveller's route across a tract of country may be traced in section, and the value of many of his local remarks greatly increased.

6. Observations continued even for a few days in the equatorial parts of the globe, suffice to determine approximately the diurnal barometric fluctuation. (152, &c.) The hours seem to be everywhere nearly the same.

7. Optical meteorological phænomena of all kinds admit of being peculiarly well studied, from the varying points of view in which the traveller is placed. The diameters of rainbows, halos and coronæ, observed with due accuracy, and the abnormal phænomena which occasionally accompany these appearances, are facts of which as yet we possess but a slender stock. We may specify the following subjects of inquiry:—

(*a.*) The colours of the sky, their optical composition, and connection with the hygrometric state of the air. (254.)

(*b.*) The polarization of the clear sky, (observed with Savart's polariscope) the position of the neutral points, its variations, and the cause of the inversion of the plane of polarization. (260.)

(*c.*) The diameter of the rainbow, and *contemporaneous measures* of the distance of the supernumerary bows from the primary. The *distance* between the Primary and Secondary rainbow, measured from the brightest part of the Red. [This last is an easy and important observation, especially if accompanied with a measure of the distance of the red of the first supernumerary bow from the primary red.] (264, 271.)

(*d.*) The diameters (in different directions) of the Great Halos, (280); the condition with respect to polarization of the parhelic circle, and other rarer appearances.

(*e.*) The phænomena of *glorified shadows*, (298, &c.) in all their particulars; and the state of polarization of the successive rings. To compare the diameters of the *direct* coronæ and those by reflection formed in the same cloud.

338. The traveller on lofty mountains possesses peculiar facilities for the following kinds of observation :—

8. The decrement of temperature in the atmosphere. (51.)

9. The force of solar and nocturnal radiation at different

heights. The effect of *atmospheric* radiation in the day-time, in clear and in cloudy weather. (72.)

10. The improvement of the theory and practice of barometric measurements.
11. The dryness of the higher strata of the atmosphere. (190.)
12. The *formation* of clouds, their *structure* and *temperature* (this last point is one of very considerable interest, viz. to compare the temperature of the air within a cloud with that of the comparatively dry surrounding air).
13. The formation of storms, especially thunder-storms, and the origin of hail. Perhaps no mountains in Europe are so well adapted for these observations as the middle and western Pyrenees.

339. Besides these and similar observations which experience will suggest, the traveller may often do something in the way of recommending local researches to intelligent persons situated on the spot. He may at once afford them the *knowledge* (which is all that many require) how to make their efforts useful,—the *stimulus* to exertion by undertaking to turn their labours to good account,—and the *means* by providing them with simple instruments, or by comparing their instruments with his own.

Addition to Article 125.

A paper by Dr. Richardson on the frozen soil of North America appears in Prof. Jameson's Journal, Jan. 1841.

Addition to Article 195, *on Wind.*

Since this was written, Mr. Osler presented at the Meeting of the British Association at Glasgow, perfectly satisfactory proof of the close connection which subsists between the diurnal curve of Temperature and the Force of the Wind. The same analogy appears to have been made out by Mr. Rutherford, at Kingussie, in Inverness-shire (who has been engaged in hourly observations under the direction of Sir D. Brewster), although, not having an anemometer, he has been unable to give to it the precision of a law, as Mr. Osler has done.

ERRATA.

Page 39, 2 lines from bottom, *for* instruments *read* instructions.
—— 44, first line of note, *for* animal *read* annual.
—— 137, line 9, *for* $\frac{1}{2185}$ *read* $\frac{1}{2183}$ inch.

CONTENTS

OF THE

SUPPLEMENTARY REPORT ON METEOROLOGY.

Report on Professor Whewell's Anemometer, now in Operation at Plymouth. By Mr. Snow Harris, F.R.S., *&c.*

[With a Plate.]

Any one who has at all considered the nature and object of Whewell's Anemometer will readily admit of how great value to Meteorology the results of its indications must prove;—since they put us in possession of a sort of figurative delineation of the total amount of the aerial current in any direction; and finally enable us to arrive at what Mr. Whewell has not unaptly termed an *annual type* of the winds for any given place:—by comparing the types of different places with each other, the general annual movement of the atmosphere may be in some degree ascertained.

The want of an instrument which could figure at once the direction and proportionate velocity of a given current, so as to obtain an integral result, has been long felt in Meteorology. Common anemometers merely register the time of a given wind from a certain point, and leave its velocity out of the question; and although others of a more improved kind register also its pressure on a given area, yet there are none, so far as I know, which give the complete and truly valuable result obtained from Mr. Whewell's, viz. the total quantity or integral effect of the wind at a given place.

Impressed with the great importance of such a result to Meteorology, I have frequently, since the Anemometer was entrusted to my care, given attention to the difficulties in its practical working, and have endeavoured to render it more easily manageable by ordinary observers. The objections hitherto made to the use of this machine are not altogether without foundation. They principally apply to the difficulty of obtaining instruments which may be taken as sufficiently comparable; to the want of constancy in the operation of the same instrument, owing to deterioration in the wheel-work from various causes; to the liability of the machine to become damaged in storms; and to the difficulty of repair.

Mr. Southwood, who attended to the Register of the instrument for some time, and who communicated the results at the Meeting of the Association held at Liverpool, in 1837, made several valuable improvements in its construction. We have not until

very recently succeeded in correcting the defects attendant on the working of the machine generally.

The recent improvements, in effecting which the sum of 10*l*. granted by the Association at its last Meeting at Birmingham has been expended, I now propose to describe; and as no particular description of the Anemometer by drawings has ever yet appeared in the Reports of the Association, it may not be amiss to give an account of the whole as it now works, since I cannot but think it entitled to considerable attention, and that it must eventually come into general use in Meteorology.

For the carrying on these recent improvements, the scientific world is indebted to Mr. Kerr of this town, on whose house the machine is now at work, and who has kindly undertaken to attend to the Register.

Plate I. AAA, figs. 1 and 2.—is a circular metallic plate, moveable about an axis D, by the action of the wind on a vane V, fig. 2. A small windmill fly W, formed of brass planes and turned at an angle of 5 degrees with a plane perpendicular to the direction of the wind is fixed on this plate. The fly revolves by the action of the wind, against which it is kept by the vane V, and gives motion to an endless screw *a*; this screw operating on a vertical wheel *b* gives motion to a horizontal wheel *d*, through the intervention of a second endless screw, not seen in the figure, and placed on its axis. This last wheel *c* is placed at the extremity of a long vertical axis M, figs. 1 and 2, upon this is cut the thread of a fine screw carrying a nut M, figs. 3 and 10. The nut M supports a pencil *p*, figs. 10 and 3, which acts by means of a balance weight *q* against a fixed cylindrical barrel D, fig. 3. The vertical axis of the plate A moves by the action of the wind on the vane V through the centre of this barrel, as in fig. 1, and thus by the revolution of the fly, and the action of the vane in turning round the plate, the pencil is caused to descend and trace a line on various parts of the cylinder D, fig. 3. There are 16 vertical lines painted on the barrel, corresponding to 16 points of the compass, as in figs. 3 and 12; hence, whilst the vane V by turning the plate A causes the pencil to apply itself to that line coincident with the direction of the wind, the windmill W causes it to descend and trace a line proportionate to its velocity for a given time—the motion of the fly being by the toothed wheels and screws fig. 1, so reduced, that for 10,000 revolutions, the pencil only descends $\frac{1}{20}$th of an inch. The barrel D is varnished white, and readily receives the trace of the pencil in a thick irregular line, the middle of which indicates the mean direction and velocity of the wind.

When the pencil has descended to the bottom, it must be

again replaced at the top and the Register recommenced. The vane V consists of two inclined planes as seen in figure 1, and is placed so as to be nearly in the prolongation of the axis of the fly. This arrangement has been found to preserve the direction more completely and maintain the position of the fly in direct opposition to the current. The wheel-work just described is effectually defended from wet and other atmospheric damage by means of a close cover C, fig. 4, fitted securely and closely over it.

In the instrument hitherto in use, the registering apparatus D, fig. 3, is placed within a small wood cover and the whole exposed to the wind on the ridge of a house or other elevated place. We have found it, however, necessary to set the whole up in a more commodious and permanent manner. A small lantern of wood about 3 feet square and 4 feet high, within which the registering apparatus is placed, fig. 3, has been erected on the top of a house, the circular plate A A in figs. 1 and 2, being moveable over its summit and toward which it converges. The vane and fly are thus freely exposed to the wind whilst the registering apparatus descends within.

In order to sustain the vertical axis upon which the plate A turns, a small beam BB, figs. 3 and 6, is placed across the bottom of the chamber hollowed at E, fig. 3, in a half circle. The hollowed part E carries an iron ring R, figs. 3, 6 and 12, of about 4 inches diameter fixed to the beam B by three arms. Within this is a second ring of brass *r*, fig. 6, forming the nut of a third ring H, fig. 7 and 12, which can be screwed within the former and removed at pleasure by means of a small forked lever L, fig. 8. These rings preserve the position of the register barrel D, fig. 3, and admit of the easy motion of the axis of the plate A in the following way:—the lower extremity of the barrel terminates in a solid cap of brass *t t t*, figs. 3 and 5; this cap *t* fits within the rings R *r*, fig. 6, and there is a stud of brass *s*, fig. 5, projecting from it corresponding to a notch *r*, fig. 6, in the fixed ring; the position of the lines on the barrel indicating the direction of the wind is hence determined. The barrel D, fig. 3, is passed up through the ring R on the descending vertical axis of the plate D, figs. 2 and 9, until its solid ring *t t*, fig. 3, comes in place. It is then finally secured by screwing up the fixing ring H, figs. 7 and 12. When the barrel is thus secured, a screw N, figs. 3 and 5, carrying on its extremity a polished centre, is screwed up through the bottom of the brass cap of the barrel until it reaches the point of the vertical axis D, fig. 9, of the metallic plate A A, figs. 1 and 2. It is then finally secured by a small nut N, figs. 5 and 12, turned up with pressure against the under part of the cylinder so as to prevent

any shake. The pencil and descending nut in fig. 3 work about this fixed barrel by means of two supports E H, figs. 2, 3 and 9 attached above to the under part of the plate A, and below to a horizontal clasp of brass P P, figs. 3 and 9. The clasp freely encircles the barrel when closed, and has small friction wheels W W W, fig. 9, inserted in it; the extremity or point of the screw M, figs. 3 and 9, moved by the windmill, turns upon this clasp, as at P, fig. 9: this clasp is shown in this figure open, by means of the joints at P P. This arrangement enables the observer when the pencil has descended for any given time, to remove the fixed barrel D and substitute a similar one, on which the register is continued, whilst that just removed is read off and transferred at the observer's leisure and convenience. The process of tabulation becomes in this way a very simple affair. The removal of the barrel and replacing of the pencil at the top of the scale is easily effected. The nut N, figs. 3 and 5, is first removed and the screw within withdrawn; the brass ring H, fig. 7, is then unscrewed by inserting the points of the bent lever L, fig. 8, into the small holes of the ring seen in figs. 7, 3, and 12. Finally the barrel is withdrawn from off the axis and another substituted as already described.

The mechanism of the pencil is represented in fig. 10. In this figure M represents the nut traversing the screw S S. This nut is made in two parts and is held together by a steadying pin *u* and a clamp screw C. One of the standards of support E, figs. 3 and 10, passes between this clasp and the steadying pin, by which the pencil is faithfully steadied in the course of its descent along the cylinder. There is a small projecting arm *n* on one side of the nut, to which is attached by means of a centre pin a curved piece *o*; this piece is moveable about the pin carrying within the curve a small knob of brass *v* set within the curve on an axis *a*. The pencil *p* and balance weight *q* are attached to this knob *v*, and thus the pencil is gently pressed against the cylinder as shown in fig. 3. The lower part of the thread of the vertical rod *s* on which the nut travels is left plain and smaller than the screw above, as seen at P, fig. 9, in order to allow the nut to fall freely off; hence if the instrument has run out at any time before attention is again given to it, damage to the fly and wheel work above, by the resistance which would otherwise ensue, is prevented. When the barrel has been replaced we have merely to turn back the screw C, fig. 10, and run the whole up to the head of the cylinder: again clamp the nut, and the Anemometer continues to register on the barrel as before.

In order to measure and transfer the amount of wind, there is

a scale fig. 11, graduated into tenths of an inch, and terminating in a concave rest G, adapted to the register barrel; this scale is applied accurately along the barrel on which the pencil has registered the amount of wind, as shown in fig. 12. There are two sliding-pieces *p p* on this scale; these are set so as to inclose the amount of wind in any given direction and the result read off on the scale. This may be also easily effected by a fine pair of compasses and a common scale.

The cover C, fig. 4, is so contrived as to be easily removed at any time, being fixed on the plate A by four small studs and a clamp screw; a small trap in the roof enables the observer to inspect the wheel-work frequently, and occasionally apply a little oil to the pivots. The action of the machine is hence preserved in a sufficiently uniform state; and I have little doubt that the velocity of revolution of the fly may be fairly assumed as proportional to that of the wind. The cover C has been found to give the wheel-work the required protection, and the instrument now in operation here is preserved so as to be quite consistent with itself. It would not be at all difficult to construct anemometers, which if attended to in this way would prove very comparable with each other, especially if they were all made by the same person, or according to the same proportions in every respect; and if the respective rates of motion under the same current were compared at first with a standard instrument, a fair degree of accuracy must unavoidably be arrived at. The difficulties in this respect are not greater than those incidental to any other machine in which the effects of wheel-work and friction have to be considered, as for instance in the rates of different chronometers. If the different pivots were set in agates, and the point of the steel axis of the fly allowed to turn against an agate instead of bearing upon a shoulder, the instruments would maintain a very uniform action.

This valuable instrument being now effectively at work, I trust at the next Meeting of the Association, to have completed a graphical delineation of the integral amount of wind at this place for a whole year without any intermission.

The sum voted by the Association for the purposes of Osler's Anemometer has been applied in completing the repairs and alterations found requisite; in the expense of tabulating the results both of the instrument here and at Birmingham; and to other expenses incidental to the observations now in progress. Mr. Osler will be prepared to lay some of the results before the Physical Section of the Association.

The remaining sum entrusted to my care for carrying on the original hourly series of Meteorological Observations here, has

been applied as usual in defraying the expense incurred on account of the Hourly Register of the Barometer, Thermometer, &c. I have included the results of these Registers for the year 1839 in my last Report.

Plymouth, September 10th, 1840.

Report on "The Motions and Sounds of the Heart." By the London Committee of the British Association, for 1839-40.

The following Report consists of two distinct portions; the former consisting of experiments performed at King's College, in 1839, by the London Committee for 1838–9; and the latter detailing the experiments of the Committee for 1839–40, performed at the Marylebone Infirmary in the present year. The former series, performed in conjunction by Prof. Todd, Dr. C. J. B. Williams and the Reporter, with occasional assistance from Dr. Roget, were commenced but not completed, owing to the difficulty of procuring subjects and other circumstances beyond the control of the Committee. No report of those experiments was consequently presented at the Birmingham meeting, or has yet been published; and an account of them is therefore now prefixed to the report of the proceedings of the Committee for the current year.

The experiments of 1838–9 were performed with the view to determine the physical and pathological causes of certain modifications of the motions and sounds of the heart that are presented by disease; a chief object being to ascertain how, by mechanical and other irritations and by displacement of the heart, murmurs could be produced; how also by inflammation. Whether for example, the pericarditic friction sounds depend on deficient lubrication of the pericardium, or on vascular turgescence, or are dependent solely on the effusion of lymph;—how far also the natural sounds might be impaired by interrupting the action of the valves in the living subject, or by spontaneous or artificially excited abnormal action in the muscular parts of the cavities without structural lesion. Another inquiry was this—How far do the motions and sounds of the heart in the lower animals correspond with those of the human subject; whether for example, in birds and other animals that differ more or less from man in their cardiac anatomy, there be not corresponding differences in the cardiac sounds and motions? To these questions the experiments for 1838–9 supply answers in most cases, which are satisfactory in the opinion of the Committee to as great an extent as could be calculated on from so limited a number of observations: they feel however that the experiments were too few finally to decide any point of much difficulty or importance, and that

further trials under more favourable circumstances are very desirable. The experiments referred to are the following:—

London Committee.—Experiments for 1838–39.

Observation I.

June 14th.—Present, Doctors Roget, Todd, Williams and Clendinning.

Subject, an Ass, about three months old. Pulse about 60, regular. At 8 o'clock A.M. a long fine needle with a silver canula was passed into the chest, at the left margin of the sternum between the ribs to the depth of two inches. The needle exhibited motions corresponding to those of the heart. The needle was withdrawn, and aqua ammoniæ diluted with four or five parts of water was injected through the canula. The pulsations of heart became immediately weak and very irregular with intermissions.

10 o'clock. Heart's action natural. Pulse 77.

12 o'clock. Pulse 70, occasionally irregularly accelerated for a few beats.

2 P.M. Still no abnormal sounds.

5 P.M. Pulse 78.

June 15th, 7 A.M. Pulse about 80.

At half-past 7, half an ounce more of solution of ammonia was injected as before, after which pulsations weak and irregular at first, but afterwards regular. Pulse 96, strong, with clear sounds.

12 o'clock. Pulse 72. Sounds natural and regular; first sound somewhat prolonged, with suspicion of murmur.

June 16th. Sounds strong. Pulse 56. Canula introduced at the root of the xiphoid cartilage into the pericardium. Some blood followed the needle. Then some strong solution of salt was injected; whence irregular accelerated action of the heart.

4 P.M. No murmur present. Both sounds distinct. Intermission every fourth or fifth beat (Cg.).

5 P.M. Pulse irregular. First sound double; generally in triplets, followed by intermission. The second sound being absent in the weak strokes preceding the intermission but distinct and loud at other times. Pulse 56, but variable (Wms.).

June 17th, 3 P.M. Pulse 56. Still occasionally retarded. Both sounds now rough; roughness most apparent about the base of the left side, and scarcely audible in the carotids (W. & T.).

June 18th, 7 A.M. Dead; but yet warm. Much blood

escaped from subclavian vein on opening chest, and coagulated afterwards. A mass of greenish-yellow lymph in the mediastinum. The cellular membrane highly vascular and easily torn. Flakes of lymph on lower anterior left lung. External pericardium marked with many straight vessels, and intermediate red striæ giving bright redness to the whole. Same in a slight degree on the interior of the pericardium, which contained two ounces of yellow serum. At base of heart most redness. Cellular substance here somewhat infiltrated with serum; whole interior of surface of heart healthy, except some slight thickening and opacity of the mitral valve. A wound plugged with lymph found on the anterior face of right ventricle.

Observation II.

June 19th.—Subject, an Ass ten weeks old. Pulse 48, regular and pretty strong. Animal weak. By pressing between the fingers and thumb the cardiac region, the thumb being on the third rib and left side, a loud blowing was excited with the first sound, which ceased on removing the pressure. After several repetitions of this experiment a short filing sound heard (by two members of the Committee) after the second sound, the first being clear. On repeating the pressure more strongly two murmurs were heard (by the same observers), one with the first sound and continuing after it, and one with the second sound (which was also weakened) and continuing after it.

After being fifteen minutes at liberty, the animal had a deep-toned blowing with the first sound, which soon ceased, but the murmur after the second sound continued.

June 20th, 8 A.M. Some murmur or filing after the second sound as before. A long needle was passed two inches and a half deep vertically to the fourth rib along the upper margin three inches from the sternum. A strong double motion was given to the needle, and a blowing, resembling a cooing, accompanied the first sound. The heart's action was increased though the animal seemed faint.

June 21st. Pulse 60. The needle again introduced three inches. As before, the needle presented rhythmical movements sternad and dorsad; that dorsad being slow and forcible, and synchronous with the first sound; that sternad being sudden, like a fall back from gravitation, and accompanying the second sound. A murmur of a blowing or whistling kind heard with the systole and diastole also, the latter variously described by different observers. Murmurs and sounds were variously altered and impaired by pressing the needle flat in different directions; on withdrawing the needle, murmurs were heard with

systole and diastole, described as rasping and filing, respectively (W. and T.), the natural sounds being distinct. The needle was introduced a second and third time; after the third withdrawal of the needle a loud creaking was heard with both sounds by two observers, but no constant abnormal sound by the third; the creaking was reported (W. & T.) to continue some minutes, when the natural sounds returned, with only a slight murmur with the second sound.

June 22nd. Animal dead, (7 A.M.) and cold. Considerable effusion of bloody serum in right pleura and mediastinum; some ecchymoses and marks of perforation on left ventricle, with corresponding marks and changes on the pericardium. Perforation three quarters of an inch below, and behind or nearer to the apex than the semilunar valves. The needle had transfixed the left ventricle, slightly wounding the mitral, and penetrating the posterior wall. The anterior lamina of the mitral had ecchymoses, and the posterior lamina was perforated near the edge, with a small fibrinous excrescence on the valve. The wound passed through the opposite posterior wall of left ventricle, around which there was ecchymosis under the pericardium.

The aortics were healthy.

Observation III.

June 23rd.—Subject, an Ass ten weeks old. Half-past 7 A.M. Pulse 60; strong and distinct. A canula was introduced about an inch from the xiphoid cartilage and for about an inch in depth, when a sound, first as of rubbing, afterwards as of blowing, accompanied the latter part of the systole; about an ounce of strong brine was then injected, when the pulsations became tumultuous and irregular, and the sounds obscure, with loud gurgling (probably from injection of air).

3 P.M. Sounds obscure, but more distinct towards the base, where a short creaking (Wms. and Tdd.) or blowing (Cg.) accompanied the first sound, which was not audible in the arteries. Pulse irregular.

June 24th, 3 P.M. Pulse 90, and regular. Sounds more distinct than yesterday; and towards the base of the heart, accompanied by leather or parchment sound. Respiration laborious. Tender near the heart; but eats well and is lively.

June 25th, 7 A.M. A loud parchment rubbing murmur with each of the sounds, which otherwise were distinct and natural. Pulse 80.

8 A.M. Jugular vein opened. Copious hæmorrhage. Heart's action became rapid, with slight rubbing sound; soon however

became slow and strong, with superficial loud grating or rough sound; and becoming gradually weaker, soon ceased. One ounce of serum in left pleura. Two to three ounces in pericardium. External pericardium exhibited several striated patches of minute vessels. The cellular tissue was infiltrated with serum, and the serous membrane was easily detached. No lymph on the inner surface of the pericardium, but the heart was completely coated with thin membraniform soft lymph, thickest at the septum, and near the base. On the anterior and posterior surfaces numerous minute depressions or lacunæ were seen in the lymph. The lymph was easily removed. On the left ventricle near the apex was an oval space of an inch by an inch and a half, of bright red patches, seeming partly vascular, partly ecchymotic, about the middle of which was a punctured wound and a clot in the muscular tissue beneath, and some ecchymoses under the corresponding endocardium. The interior of the heart healthy. The serum from the pericardium after standing separated into crassamentum and liquid.

Observation IV.

June 23rd.—Subject, a stout Ass two months old. Pulse 60–70; strong, with sounds very loud.

Quarter to 4 p.m. A needle was introduced at the upper edge of the fourth rib, three inches from the sternum, and one inch deep. The heart's action was accelerated, with obscure blowing with the systole.

The needle being withdrawn, the heart's action was slower, with double creaking or leather sound, reported by two observers as accompanying both sounds, which became stronger after a few minutes. Heart's action varying in regularity.

Quarter of an hour after. Leather sound at the site of the puncture, not at all at the apex. Natural sounds there quite distinct.

June 25th, 7 a.m. Both cardiac sounds loud, with sounds of friction at the basis cordis.

June 26th, 7 a.m. Normal cardiac and friction sounds as before. A long needle three times introduced in different directions between the third and fourth ribs, and three to four inches from the sternum, without any marked effect, except sometimes on strongly depressing the handle towards the sternum, a blowing with first sound was heard, the second sounds being normal (rubbing rather than blowing sound, Cg.).

On first introducing the needle a scratching noise was sometimes heard with the systole, as if from the point hitching against the heart's surfaces.

A fine curved tenaculum about two inches in the curve, was passed two to three inches from the sternum, behind the third rib, with the point toward the spine; and when at the greatest depth, the handle was depressed toward the sternum, so as to move the hook outwards toward the ribs; a loud blowing then attended the first sound, which was distinct; the second sound was wanting, when the handle was most depressed, and obscure when the handle was somewhat raised, and restored to full force when the hook was withdrawn.

Half an hour after. The first sound was accompanied with blowing between the first and third ribs, while a friction sound accompanied the second sound (the Reporter called it altogether *friction sound*, with both systole and diastole, but varying in hoarseness or roughness); it was faintly audible in the carotids.

Half-past 3 P.M. Still slight friction and blowing (roughness only of friction, Reporter) increased after the animal struggled. The tenaculum was again introduced and manipulated as before; and again the second sound was stopped by drawing at the root of the arteries, and restored on releasing the hold; the first sound being accompanied by a loud whizzing, and the hoarse or rubbing sound being indistinct if not absent.

On withdrawing the hook, a transitory crackling was heard; on the introduction of the hook, the heart's action became tumultuous and irregular, and on withdrawing it, very rapid. Pulse 112. Half-an-hour after, the pulse still 112, and the first sound accompanied by murmur.

June 27th, quarter-past 7 A.M. Sounds as before; rough murmur as of friction, with first sound especially. The animal then pithed, and artificial breathing established and chest opened. Heart was acting vigorously, with the sounds distinct and normal.

First Experiment.

On introducing a finger into the right auri-ventricular orifice, first sound was accompanied with a whizz, and wanted its flap at the beginning; the whizz was accompanied by a thrill sensible to the finger introduced; the whizz ceased and the systolic flap returned on removing the finger.

This experiment was repeated several times with the like results.

Second Experiment.

The hook was introduced through the auricle with a view to hook up the tendons of the mitral valves, when the flap seemed impaired not suppressed, and the whizz was uncertain.

Third Experiment.

A finger placed on the auri-ventricular opening externally experienced in the systole the same vibratory or jerking motion as would in diastole be felt over the aortics ; and to the eye the same motion was visible in the former during the first sound *at its commencement*, as at the arterial openings during the second sound (Cg.).

Fourth Experiment.

A blunt bistoury was introduced into the auri-ventricular opening through the auricle, and the tendons of the septal lamina of the mitral were cut partially, when the *flap* of the first sound was impaired but not destroyed.

On examining the heart were found several marks of perforation of the large arteries, anteriorly to the valves, and perforations just at the opening of the coronary artery, but no valve was wounded. There were ecchymoses at the external mouths of the perforations, and attached to one wound was a clot with a fibrinous peduncle. On the surface of the right ventricle corresponding to the infundibulum, the pericardium was injected and roughened by lymph, with several scratches and punctures ; the lymph was small in quantity and granular in appearance. A wound in the septum was plugged with lymph, as were all the flesh wounds in the interior of the heart.

Observation V.

June 29th.—Subject, a Donkey three months old. Half-past 7 A.M. Heart's action quite normal. A tenaculum passed four inches from the sternum between the third and fourth ribs ; the handle having been lowered toward the spine, there was a whizzing heard with the first sound; but the second sound was only a little weakened.

The whizz or blowing contined after the experiment with the systole, and after the flap of the valves ; but soon became intermittent, and gradually disappeared.

June 30th. A fine canula was passed through the sternum an inch from the xiphoid cartilage, and about twelve ounces of warm water were injected ; the cardiac sounds became presently apparently distant, especially toward the sternum ; on withdrawing the tube, the sounds were still distant with little impulse, but were otherwise normal, except that occasionally the systole was acompanied by blowing during embarrassed respiration. A tumour formed under the integuments of the sternum, through which the cardiac sounds were very faintly heard, and without impulse.

Heart's action much accelerated.

July 4th. Animal pithed, and artificial breathing established. The experiments on the mitral valves then repeated. The left auricle was inverted by the finger and the valves impeded or kept asunder by the finger, in the auri-ventricular opening, when various murmurs accompanied or followed the first sound; the second sound being simply either much weakened or suppressed; and the normal sounds returned on the withdrawal of the finger. This experiment was often repeated with similar results.

A finger being placed on the exterior circumference of the mitral and aortic valves respectively at the same moment, similar jerking motions perceived in each; at the closing of the valves and evolutions of the two cardiac sounds, the finger, when in the auri-ventricular opening, was sensible of something like flapping, pushing and tension, as it were, in and by the valves, and the supposed edge of the valve was felt tense in systole; and, if divided by the point of the finger, the edges of the opposite valves were thought to give a feeling of resistance such as valvular tension must cause, supposing such tension to occur. The first sound was protracted and dull, wanting the sharply defined beginning such as a flap would give when the valvular action was interrupted by the finger. The first sound was obscure, but audible on extraction of the heart, when the organ was irritated to contraction.

Observation VI.

July 3rd.—Subject, a Turtle, weight 150 lbs. No distinct pulsation could be heard externally. After decapitation and removal of the callipée the heart was felt by one of the Committee, pulsating regularly, and two distinct sounds were heard (Wms.), with an interval between; the heart ceased beating too soon to allow of the other member of the Committee (Cg.) making any satisfactory observation.

Observation VII.

Comparative Observation.

The observations of the Committee on the motions and sounds of the Heart had been previously made almost exclusively on donkeys and dogs, animals whose cardiac structure and modes of action are generally known to agree with those of the human subject. It was therefore thought very desirable to extend their observations more widely over the scale, as by such means it was thought some useful generalization might be obtained, and the views of the Committee be at

the same time subjected to a new and interesting test, and, if sound, fully confirmed, but if defective, corrected; and in any event, that their future conclusions would be based on a greater variety of facts and a more comprehensive induction. The Committee therefore made arrangements for the purpose of visiting the Zoological Gardens, and examining as many of the animals there as could easily be approached by strangers for the purposes of auscultation, &c. Before visiting the gardens, the Committee met at the Hunterian Museum, for the purpose of inspecting the preparations illustrative of the physiology of the heart that exist in that national collection, and were obligingly assisted in their search by Mr. Owen, Professor of Comparative Anatomy to the Royal College of Surgeons. With the aid of the anatomical data collected at the Royal College of Surgeons, the Committee there entered at once on their examination of the living animals. Before stating any particulars of our observations, it is proper to say that, in our examination of the wilder animals, we were much indebted to Mr. Youatt, the distinguished veterinary surgeon of the establishment, without whose kind assistance it would have been out of our power even to have attempted anything in several instances. Even with Mr. Youatt's aid, we found it extremely difficult, in many cases, to make satisfactory observations; so that, in but a portion of the subjects was it found practicable for the whole of the Committee to verify results to their satisfaction.

The animals sufficiently examined by all are distinguished in the following enumeration:—They are,

1. The Ostrich.
2. The Ourang-Outang.
3. The Leopard.
4. The Seal.
5. The Balearic Crane.
6. The Common Crane.
7. The Brahmin Bull.
8. The Puma.
9. The Indian Antelope.

Other animals examined to the satisfaction of some members of the Committee, were—

10. The Elephant.
11. The Dromedary.
12. The Antelope.
13. The Water Buffalo.
14. The Giraffe.

15. The Lion.
16. The Nylghau.
17. The Wapiti Deer.
18. The Hyæna.

In No. 1 (the Ostrich). The pulse at the heart was very vigorous, and about 60 in the minute. The systolic, or first sound, was long and obtuse; and the second, or diastolic sound, was short, and rather obtuse.

In No. 2 (the Ourang-Outang). The pulse was quick, and the cardiac sounds and rhythm like those of the heart of a child very exactly.

In No. 3 (the Leopard). The pulse was 60. The first sound normal, but the second rather indistinct, as compared with the human standard.

In No. 4 (the Seal). Pulse not materially different from the human. First sound long and obtuse, second sound short and clear.

In No. 5 (the Balearic Crane). Pulse 130 to 140. Animal phthisical. First sound long and obtuse, second sound indistinct.

In No. 6 (the Common Crane). First sound short, and no second sound heard.

In No. 7 (the Brahmin Bull). Pulse 80. Animal phthisical. First sound long and obtuse, second sound indistinct.

In No. 8 (the Puma). Pulse 86. Animal sickly, probably phthisical. Grating murmur with the first sound.

In No. 9 (the Indian Antelope). Long obtuse first sound, short flapping second sound.

In No. 10 (the Elephant). Pulse 36. Long and obtuse first sound, and relatively short and flapping second sound.

In No. 11 (the Dromedary). Pulse 48. Long and obtuse first sound, short second sound.

In No. 12 (the Antelope). The first sound longer and duller, the second sound shorter and sharper.

In No. 13 (the Water Buffalo). Pulse 60. Blowing murmur after the first sound, no second sound heard.

In No. 14 (the Giraffe). Pulse 50. Second sound sometimes double.

In No. 15 (the Lion). First sound long and obtuse, second sound short and flapping.

In No. 16 (the Nylghau). First sound normal, second sound indistinct.

In No. 17 (the Wapiti Deer). Pulse 60. First sound long and obtuse, second sound short and flapping.

In No. 18 (the Hyæna). Long obtuse first sound, short second sound.

Some other animals were attempted, but without success; viz., the Dzagetai or Wild Ass, the Rhinoceros, the Cassowary, and some others. As a general observation, the Committee may state, that wherever the two sounds of the heart could be distinguished, the character of those sounds and the rhythm of the heart's motions appeared to correspond with those of the human heart, due allowance being made for differences of size in the animals, differences of temperament, and the circumstances of excitement or of disease under which many of the animals laboured, when they were subjected to auscultation, &c.

Experiments of the Committee for 1839–40.

In consequence of having been nominated to conduct the experiments on the motions and sounds of the heart for the current year, without being associated with any colleagues, I thought it desirable to avail myself of the assistance of such of my friends, including the other members of last year's Committee, as could attend, and I accordingly requested the co-operation of a considerable number of gentlemen known to the public; of these, several were enabled to attend on numerous occasions, and one of them, Dr. Boyd, on every occasion; so that every observation and experiment has been participated in or at least witnessed by one, or, in most instances, several of the following gentlemen:

Professor C. J. B. Williams.
George Gulliver, Esq., F.R.S.
John George Perry, Esq.
Dr. G. Hamilton Roe.
Dr. George Burrows.
Charles Cochrane, Esq.
Dr. Rutherford.
Francis Kiernan, Esq., F.R.S.
J. Liddell, Esq.
Francis Samwell, Esq.
Dr. Edwin Harrison.
R. A. Stafford, Esq.
Benjamin Phillips, Esq., F.R.S.
Dr. Robert Boyd;

and other gentlemen, private friends of the Reporter, and the last four-named gentlemen his colleagues in the medical staff of the St. Marylebone Infirmary.

The experiments were performed in a convenient locality immediately adjoining to the Marylebone Infirmary, and principally on donkey colts of a few months old. In the latter part of the series other animals, and especially dogs, were used, partly for economy, and in order that the limited pecuniary resources of the Committee might not be prematurely exhausted, and partly because certain experiments contemplated were expected to prove more easily and decisively practicable on the larger heart of the ass than on any smaller, such as that of the dog; and that, in any event, it was desirable to extend the range of observation, as far as practicable, over the animal scale.

The mode of preparation was in all cases nearly the same. In almost every case sensibility was withdrawn as completely as was practicable by one method or the other. In donkeys we availed ourselves of the stupefying property of the woorara poison, for a packet of which the Reporter had been indebted, since 1838, to the kindness of Sir B. C. Brodie, Bart. The woorara was brought into operation by injecting a couple of grains of it, partly dissolved, partly suspended in water, into the external jugular vein, as practised by Mr. Mayo in an experiment of Dr. Hope's, and the injection was usually followed in a very few minutes by complete insensibility. In the smaller animals prussic acid was used in several instances; and in a few cases the subject was stunned by a blow on the head. Artificial breathing was used in every warm-blooded subject, by means of a bellows and long flexible tube kept loose in the trachea. The chest was opened nearly as directed by Galen*, and as practised by former Committees; five or six ribs were separated from the sternum and broken near the articulations, and bent back over the vertebræ. In every case, whether during the preparation or subsequent observation, all convenient means were used, as advised by Galen†, to prevent or lessen hæmorrhage, in order to avoid as much as possible the anomalous modes of action attending extreme vascular depletion, and to prolong the opportunities of observation and experiment.

The observations about to be detailed consist partly of experiments in continuation of the inquiries of former Committees, and partly of experiments made with a view to decide

* *De Admin. Anat.* l. vii. c. 12. † *Loc. cit.*

several points in dispute amongst physiologists of authority, which were not investigated by those Committees, and which seemed to the Reporter yet unsettled, and at the same time important enough to call for direct experimental investigation. The following are the principal of those undecided questions:—

1. With respect to the rhythm of the motions of the auricles and ventricles, several living distinguished physiological writers appear to hold, that those cavities act in strict alternation with each other, and not continuously or in immediate succession, the auricles being first always in systole and diastole, and the ventricular actions being last before the *Rest*, as described by Steno, Harvey, Lancisi, Haller, Senac, &c., and by Hope, Williams, Carlisle, Pennock, and Moore, and other living authorities.

2. With respect to the share in the circulation due to the auricular systole, it has been held to be active and of much importance, by Hervey, Senac, and others; while several living writers of great weight, adhering apparently to the views of Galen, Vesalius, &c., seem disposed to refuse to the auricles any very influential or positively important share in the cardiac operations; for examples I may cite Dr. Elliotson, Prof. Bouillaud, Dr. Hope, Sir B. C. Brodie, &c.

3. With respect to the shape and dimensions of the ventricles in systole, it was held by Galen, Vesalius, Harvey, &c., that the heart is shortened in diastole and lengthened in systole; but the observations of Steno, Lower, Lancisi, Haller, and others, gave currency to opposite views; of late, however, the ancient opinion has been revived, for example, by Prof. Burdach and Prof. Bouillaud, as I understand their observations, and by Drs. Pennock and Moore, the latest experimentalists on the subject that I know of, except my friends and myself.

4. With respect to the præcordial impulse, the great majority of physiologists, adhering unqualifiedly to the ancient opinion advocated by Hippocrates and Galen amongst the Greeks, and by Vesalius, Harvey, Lancisi, Senac, Haller, Hunter, and almost all modern writers, ascribe the cardiac pulsation to a blow or stroke (in the popular meaning of those words) given by the heart's apex in systole to the ribs; while, in opposition to this view, may be cited the experiments of several recent observers, and the arguments of Mr. Carlisle, of Dr. Hope in his last edition, of Mr. Bryan*, Dr. Billing, &c. &c.

5. With respect to the diastole of the heart, it was held by

* Lancet, v. 29.

Galen and Vesalius to include a strong force of suction, by which the venous current was much forwarded, and the auricles were more or less emptied; and this power of inhalation or suction has been adopted by numerous living authorities, *ex. gr.* Prof. Bouillaud, Dr. Hope and Dr. Copland, and has even been extended to the auricular diastole, *ex. gr.* by Dr. Alison and Dr. Elliotson. The exertion, however, of any such force has been distinctly refused to the diastolic state by Harvey, Lower, Senac, &c., and appears, Dr. Joy remarks, to rest on no satisfactory experimental evidence whatsoever.

6. In addition to active pulsations observed in certain animals in the veins (as in horses, rabbits, dogs, fowls, frogs, &c.), there have been noted by several experimentalists, of whom it is sufficient to name the great Haller, certain passive pulsations, viz. an abrupt diastole of the vein attending the first part of the heart's systole or the auricular contraction, and an abrupt systole of the vein attending the first part of the heart's diastole on the dilatation of the auricle; but the connexion between the venous regurgitation and the auricular systole has been doubted by several apparently, and even denied by Dr. Elliotson.

7. Reverting to the auricular functions, the systole of the auricles has usually been regarded as unattended by any intrinsic sound. Dr. Hope denies that any such sound occurs, and on mechanical grounds seems to affirm that it is not possible; and Dr. Joy calls the auricular systole a "silent" act*. Six months, probably, or more, however, before the Committee for 1840 had even begun their experiments, Drs. Pennock and Moore had, unknown to the Reporter and his friends, detected, as they conceived, an auricular systolic sound, in a series of very interesting experiments, of which an account is published in the American Journal of Medical Science, Part L., for February, 1840.

Some other often-agitated and still unsettled points have appeared to the Reporter, in like manner, to stand in need of further examination; *ex. gr.* 1. the sizes of the ventricles, &c. with respect to each other; 2. the production of sound by certain muscles, while vigorously contracting; 3. the rhythm of the cardiac and arterial pulses, &c. &c. Finding on all the preceding points considerable differences of opinion, and perceiving that, in many instances, the decision of highly-distinguished and leading physiological writers was at variance with the best hitherto-recorded experiments and observations, the Reporter found forced on his mind the conviction, that on all or most of those points further data were wanting, and

* Library of Practical Medicine.

experiments less ambiguous and more pointed and conclusive. Under such impressions, the Reporter felt himself at liberty, if not positively called on, to advert to various questions above alluded to, which had not been handled by former Committees, provided that, by any unlooked-for good fortune, if not through some new and happier experimental combinations, he should succeed in eliciting pertinent and decisive facts. Acting on such views, the Committee has put to the test of experiment, to a greater or less extent, several of those questions, with results now to be stated.

It may be proper to state, that the instrument used in auscultation was exclusively the flexible ear tube; the wooden stethoscope, comparatively inconvenient in almost all cases, being found quite unsuited for such experiments.

Observation I.

June 11th.—Subject, a Donkey about ten weeks old and sound in all respects. *Phænomena: Various spontaneous irregularities in the cardiac action and sounds;—jerking upwards &c. of periphery of internal valves in systole;—appearances of auricles in action;—effect of valvular obstruction on first sound.* Heart, when exposed, acting strongly and quickly. Second sound indistinct, and loud murmur with the first sound.

S. 1. On placing the finger on the outer periphery of the mitral valves, an upward jerk and thrilling motion sensible, similar to that observed over the arterial valves.

S. 2. At the moment of auricular systole, were noted a dimpling of the appendix, and an abrupt contraction in all its dimensions, and a sinking (as it were) downwards and inwards, followed by a gradual return to the state of prominence and distention that characterize the auricular diastole. Several times was observed a slight and partial active contraction of the auricle, followed by relaxation in the intervals of full and complete auricular systole and diastole, as if from transient spasmodic disturbance.

S. 3. The second cardiac sound observed at intervals to be for many minutes together wholly wanting, without obvious cause; no operation upon the mitral or other valves having been hitherto attempted.

S. 4. The left auricle was inverted successively by the finger and by a probe, so as to impede the action of the mitral valves; the finger was sensible, when placed in the mitral orifice, of an abrupt though gentle concussion in the systole of the ventricle, and (it seemed to me) as if it were

pushed by a cord or membrane stretched obliquely across the passage, and brought suddenly to a state of tension; and at the same time the sensation of jerking upwards was much less distinct when a finger was placed over the valve externally. The probe also, when held loosely in the orifice (enveloped, like the finger, in the inverted appendix of the auricle), was felt and seen to be pushed back in each systole between the fingers.

S. 5. At the moment of introducing the inverted appendix into the internal opening, the sharp well-defined beginning of the first or systolic sound was wanting or obscure; and that sound seemed to several observers less abrupt and more gradual in its development.

Observation II.

June 13th.—Subject, a stout Ass two to three months old. *Phænomena: Abnormal murmurs, without structural defect;—motions of the ventricle in systole, as apparent to the eye and hand;—same of the auricles;—rhythm of the motions of auricles and ventricles;—auricular hæmorrhage not suspended in diastole, and augmented in systole of auricle.*

S. 1. Heart acting normally and vigorously before the injection of woorara. Immediately after the operation was completed, a murmur was observed with the second or diastolic sound, with a slow cardiac action; the first or systolic sound being normal.

S. 2. In systole, motion first distinctly observed at the fundus, especially on the right ventricle, where any phænomena about the arterial orifice are most easily observed in animals lying on the right side; apex almost simultaneously moved with fundus. These systolic motions in the ventricles were preceded by a dimpling and shrinking inwards and downwards of the auricular appendices, but by a very minute interval, so that the auricular motion seemed as it were but the first portion of a more extensive movement affecting the whole heart.

S. 3. Before opening the pericardium, needles were passed horizontally through that organ without wounding the heart, and so that they lay exposed to the eye in their whole length, except the minute portion actually penetrating the pericardium, and over the following points,—viz. over the auricle, over the periphery of the mitral orifice, and over the apex; and observation was made through a roll of paper employed to limit the field of vision, and a succession of motions was distinctly noted; first, about the fundus and insertions of the

great arteries, and most strikingly over the appendices auricularum, and thence propagated as it were toward the free extremity of the heart, being perceived in the body of the ventricles next after the fundus, and at the apex last, as if an impulse in a compressed fluid, or a wave commencing about the insertions of the arteries, had been propagated along the heart from fundus to apex.

S. 4. After opening the pericardium, small triangular bits of white card were applied so as to adhere to the left appendix, fundus of left ventricle, middle of same cavity, and close to the apex; and observation was made, as in last experiment, through rolled paper, and with like results (as in S. 3.).

S. 5. And this seeming propagation of motion was perceived next in another way, viz. by pressing gently on the fundus and body of the ventricle and on the apex, by which was elicited a sensation, or series of sensations, as of a progressive movement of an undulatory character directed from fundus to apex, and resembling, to a considerable extent, that given by a dropsical abdomen, or hydrocele, &c., when appropriately percussed.

S. 6. During a very vigorous action of the auricles, and at a somewhat advanced period of the observation, the shrinking and dimpling, in its centre, of the appendix in its systole, was likened by several observers to an effect either of suction or of some traction exerted on the appendix from some point about the auri-ventricular opening, more especially because it seemed often separated in time from the ventricular tension, roundness and impulse (*i. e.* systole) by a scarcely perceptible interval.

S. 7. Toward the end of the observation, and during a tolerably regular and vigorous action of the heart, the tip of the left auricle was snipped off; after which the contractions of the appendix became indistinct, those of the ventricle being at first little affected. On the instant of cutting off the appendix, a profuse flow of blood occurred in a stream slightly increased by a jet during systole of the auricle, and continuous, and without any jet, during diastole.

Note.—The heart ceased to beat after about three quarters of an hour of observation, owing to the inflating tube becoming obstructed by a clot of blood which escaped timely detection; it was quite healthy; the ventricles appeared not to differ in size.

Observation III.

June 22.—Subject, a Donkey about six months old, in good health. *Phænomena: Results of application of pressure in various ways to the ventricles;—rhythm and manner of motions of fundus and apex in systole and diastole;—motions in the arteries and over the valvular orifices;—action of the sinuses in systole of auricles;—shortening of heart in systole;—effects of wounding an auricle, &c. &c.*

S. 1. Callipers were applied to the ventricles, as if to take the diameter of the heart. The legs of the callipers before use had been fastened together by an elastic chord of considerable resisting power. In whichever direction the instrument so prepared was made to embrace the ventricles, whether exactly transversely or obliquely, the uniform result was, that the legs of the instrument were separated with force, and receded from each other in each systole, and approached each other in each diastole with depression of the part of the parietes they pressed on; which depression wholly disappeared in the systole, giving place to an opposite state of the parts, or to a state of convexity and apparent protrusion.

S. 2. The finger and thumb were then applied to opposite sides of the ventricles, and were felt to be abruptly pushed outwards in systole, and to approach each other in diastole, if acted on even slightly by the flexor muscles, and with marked depression of the parietes in diastole, during which no sense of active resistance was experienced.

S. 3. A wooden stethoscope was then placed on the ventricles, and kept erect by means of a roll of paper large enough to give the instrument full freedom of motion; and the uniform result was, that wheresoever placed on the ventricles, the stethoscope was heaved up with a jerk at each systole (to the height of half an inch near the fundus), and subsided at once in diastole, causing in the parietes a deep depression, which was wholly removed by the systole, and succeeded by an opposite shape of the surface.

S. 4. To the eye and hand the fundus appeared to become round, hard, and elevated, and to give impulse somewhat sooner than the apex, as if the systole was developed earlier about the fundus than at the free extremity of the heart.

S. 5. To the fingers, during the systole of the ventricles, a feeling was communicated, as of an undulation in a compressed fluid, very distinct, and directed from fundus to apex, and resembling sensations familiar to physicians in ascites, hydrocele, &c., when properly percussed and manipulated.

S. 6. On touching the arteries close to the heart a feeling, as of efflux and reflux, was very distinct, especially in the aorta, the former coinciding with the systole of the ventricles, the latter with the diastole. At the same moment with the outward current in the arteries, or during the ventricular systole, a peculiar jerking upwards of the periphery of the auri-ventricular orifices,—and a similar eccentric movement was observed over the arterial openings during the reflux current or undulation in the vessels, *i. e.* during ventricular diastole.

S. 7. The sinuses of the auricles were found by the touch to contract vigorously, before the ventricles considerably, and even before the shrinking, &c., or systole of the appendices.

S. 8. Small three-triangular pieces of white card were made to adhere to the fundus and apex cordis respectively, and observation was made through a roll of paper sufficiently large to take in, at a convenient distance, both extremities of the organ, and held so that each white object rested on a distinct limb of the tube's mouth, and every change of distance between the points dotted white was readily detectible,—and the uniform result was, that the apex approached the base in systole and receded again in diastole, and the range of oscillation seemed about $\frac{1}{3}$rd of an inch.

S. 9. While the heart still acted, but with much diminished force, a cut was made in the right auricle and a copious flow of blood obtained, having slight jets in the auricular systole, and immediately before the ventricular hardening, elevation, &c., but being continuous during diastole.

Note.—The ventricles appeared not to differ in size on careful examination—post mortem cordis.

Observation IV.

June 27.—Subject, a stout Ass three to four weeks old. Heart acted very vigorously until weakened by hæmorrhage, and continued to beat with considerable energy for two hours, when it was extracted, still contracting. *Phænomena: Effects of various forms of pressure on the heart;—rhythm of cardiac and arterial pulses;—ventricular systole;—auricular ditto;—sound of auricular systole;—pulsation of cava;—auricular diastole;—spontaneous or incidental variations in cardiac sounds;—protrusion of septum into right ventricle in systole.*

S. 1. A stethoscope loaded with 2 lbs. weight of shot in a bag, was placed on the heart before opening the pericardium (as in experiment 3 of last observation), and was raised at each systole with a sudden heave or jerk, and with much

force, and subsided immediately on the supervention of diastole, causing a deep depression in the previously convex surface of the ventricle. This experiment was repeated toward the close of the observation, and after the heart had been exposed for 1 hours and with like results in all respects.

S. 2. The pulse of the femoral artery, being compared with that of the heart, was found to follow the latter by a distinctly perceptible interval, but one very minute.

S. 3. To the eye the apex and fundus cordis approximated to each other in systole, and receded in diastole. The motions of those parts coincided to a great extent, but not entirely, but rather as parts of a series of concatenated movements, of which the former part was the profound undulation, hardening and rounding of the fundus, and the latter part the hardening, shortening, and slight elevation of the apex; between these successive appearances, no very distinct interval; they passed into each other by an undulatory sort of motion, commencing at the fundus, and passing with extreme rapidity along the ventricles to the apex.

S. 4. Threads were passed through the appendices of the auricles, and being held tense, so as to impede the auricular systole, were felt to be drawn downwards with much energy immediately before the systole of the ventricles, the auricular contraction being completed, while the ventricles were still developing their systole.

S. 5. Toward the close of the first hour of observation, and while the heart in its different parts acted with much energy, the auricles were observed for a time to contract with a rhythm above double that of the ventricles (owing probably to the irritation excited by passing the needle and thread through the appendices, and pulling at them afterwards), and a sound was detected resembling very much, except in volume, the first or ventricular systolic sound, and accompanying the auricular systole. The sound was short, rapid, obtuse, without any jerking motion, and coincident exactly with the auricular systole, and in number double (or rather more) the sound of the ventricular systole. This sound was found to attend the systole of the right auricle as well as that of the left, at a time when the action of the latter was too feeble to give sound.

S. 6. The large pectoral veins, especially the cava, were observed to pulsate with the auricular systole, something as the arteries do with the ventricular, but comparatively very feebly; first came the diastole of the vein and then the systole, and then the Rest, and the former followed immediately on

the auricular systole, and the latter on the diastole of the auricles, both in the inferior and superior cava; no other motion was noted in the veins.

S. 7. The diastole of the auricles was a gradual swelling and enlargement of the visible parts of the cavities in all directions, requiring for its completion as much time as several systoles would do; and followed, on the instant of the full distension of the appendices, by systole of the whole heart,—first in the auricle, and then instantly in the ventricles: during its diastole, the auricle seemed to the eye to emerge, as it were, from the sinus venosus, and to swell out from a state of collapse, such as suction inwards toward the ventricle might cause, if any such force as suction existed in the heart.

S. 8. In this, as in every observation, abnormal murmurs were observed at various moments, viz. immediately on the injection of the woorara, and at other times, but especially when pressure was made, whether intentionally or otherwise, over the orifices, exterior and interior, of the heart. Toward the close of the observation, a loud musical sound was detected in the pulmonary artery with the diastole. At various times, for short spaces, the second sound of the heart was indistinct or absent, or masked by murmurs, without obvious cause in most instances, other than abnormal modes of action from irritation, hæmorrhage, &c., exclusively of known structural changes. The first sound of the heart was often modified in various ways, and attended by murmurs, but never was wanting so long as the heart acted with any energy. Toward the close, however, when the ventricular systole had become slow and gradual from quick and abrupt, the first sound was either very feeble, or not distinguishable at all.

S. 9. The pulmonary artery was cut open; after which the first sound was still heard, but rather obtuse. A finger was then passed into the right ventricle, and the septum was felt to project convexly into the cavity, and in each systolic effort to press against the finger.

Note.—Post mortem. One valve of the pulmonary orifice was found slightly injured by a puncture made in the course of experiments, in which the parietes cordis had been irritated to abnormal action by means of a needle. Wherever the needle penetrated into a cavity of the heart, there a clot was found, or at least a coloured plug of lymph in the internal opening.

Post mortem. The ventricles were found to be of the same dimensions on careful examination.

Observations V. and VI.

July 1st, 1840.—In two observations, one on a Frog and a second on a Rabbit, the following results were obtained:—

Rhythm: The first contraction after the pause or cardiac diastole was observed in the vena cava, to which immediately succeeded contraction of the sinus, and afterwards, immediately, of the appendix of the auricles; to which latter, immediately succeeded the ventricular systole; and the diastole, or relaxation of each part, succeeded in like order,—that of the vein first; then of the auricle, of which the appendix seemed later in its diastole than the sinus or body; then of the ventricles. Those motions were much slower than in the human subject—somewhere about fifty beats per minute. The series of systoles above mentioned succeeded each other, so that at a little distance they appeared collectively like an undulation commencing at the cava, rather than a series of independent actions.—*Systole of ventricle*: In diastole the ventricle was round, full, protuberant, and dark in colour; but on the supervention of systole changed rapidly in shape and colour, from purple, becoming pale flesh colour, like veal; and from round and broad, becoming apparently narrower and more conical and depressed; being obviously lessened in all dimensions, but most strikingly in the transverse. The action of the heart lasted for an hour or more with great regularity; the auricles acted for some time longer than the ventricle, especially the right auricle.

Observation VI.

In the rabbit, the heart did not beat at any time very vigorously or regularly, and ceased altogether after 20 to 25 minutes, although respiration was maintained by the bellows with ease.

The Rhythm: S. 1. The first motion after the Pause or ventricular diastole was observed in the base of the auricles, and on the right side in the expansion of the jugular and subclavian veins, which in the rabbit, as Steno has noted, seemed to replace the superior cava. This vessel, whose dimensions were very large compared with the heart, and which wound round the root of the heart in its way to the auricle from above downwards, and from left to right, continued to pulsate for some time after the ventricles had ceased, and even after the adjoining auricle had been for some minutes inert. Nearly, but not quite, at the same instant of time with the vein, the base and then the apex of the auricle were seen to contract; after which (but not so quickly as might have been expected from

other observations, owing probably to delay in the establishment of artificial breathing) the ventricles entered into their systole, and the diastole followed in like order; first, the venous expansion, next the base and appendix of the auricles, and last of all the ventricle.

S. 2. In the systole some change of colour was observed in the ventricles, from darker to paler, and the same in the auricles.

S. 3. Toward the close of the observations, the auricles acted much more frequently than the ventricles, and especially the right auricle. In the ventricular systole the apex was thought to move slightly outwards and to the left, or away from the septum or central axis of the heart.

Observation VII.

July 2nd.—Subject, a snake of good size, poisoned with prussic acid, so as to be insensible. Heart beating very slowly and rather irregularly at first, from 15 to 20 beats per minute only.

Rhythm of motions: After a long pause, first motion observed in sinus of auricle, and then in appendix, being the auricular systole; immediately after which the ventricular systole, but with no complete interval between the end of one and beginning of the other systole. After the systoles respectively came the diastoles in like order, and then a long pause, equal sometimes to 3 or 4 or more beats.

At each auricular systole, a swelling observed in the cava and pulmonary veins, extending some way down from the heart. This appearance resembled a wave of reflux excited by the action of the auricle. It was not observed in any part beyond a point of the vessels on which pressure was made. In the systole, the ventricle shrank concentrically, being shorter and narrower, but also rounder and more oval, than in diastole; the ventricle (which might be called bicornute, being obtusely pointed at either extremity,) had either horn or extremity raised slightly in systole, and depressed again, as if by gravitation, in diastole. The cavities systolized and diastolized still after the observation was completed, or for more than an hour, and more regularly than at first.

July 2nd.—The ventricle ceased beating after about twenty hours, but the auricles were still pulsating regularly after more than twenty-four hours. The rhythm of the motions of the heart as before, but the reflux wave or diastole of the veins now less distinct, owing probably to the emptiness of the heart. And in lieu of the regurgitation wave marked by a

diastole, followed by a systole, and then a pause in the veins, there was observed an opposite order of the motions, viz. 1. venous systole; 2. venous diastole; 3. then the pause. Several times the motions of the veins were observed alone, and not preceded by auricular contraction, or accompanied by it, as, toward the close in other observations, auricular contraction had often failed to excite or be followed by ventricular systole.

Observation VIII.

July 4th.—Subject, a Donkey nine months old, in good health. Pulse beating well in præcordia about 70 or 80. Operation of injection tedious, with considerable hæmorrhage; whole operation lasted half an hour, and heart acted for considerably more than an hour. When opened, the heart was beating quickly (above 100) but regularly. Second sound indistinct.

Phænomena: Effects of pressure on the heart;—action of threaded auricles;—no sound, and why;—manner of auricular diastole;—resistance to pencil in mitral orifices, and how caused;—pulsation of cava;—phænomena of ventricular systole;—mechanism of cardiac impulse;—valvular jerk over the mitral opening in systole, and modifications of first sound artificially produced;—hæmorrhage from left auricle;—relative sizes of ventricles.

S. 1. The stethoscope, loaded with 4 to 5 lbs. of shot, &c., and placed on the ventricles as before, was jerked up by each systole, and subsided and deeply indented the parietes in each diastole.

S. 2. The callipers were applied as before, but with a tension much exceeding that formerly used, and with a similar but not equal result; the heart being considerably less vigorous, as well as the spring much stiffer. The action became much hurried under the pressure of the instrument, but its legs were pushed asunder with force in systole, and a deep indentation was caused by them in the parietes in diastole, which did not wholly disappear sometimes in systole.

S. 3. The tip of the appendix of the left auricle was threaded as before, and the auricle and ventricle acted nearly but not exactly in alternation, and the thread was felt to be forcibly drawn downwards at the moment of auricular dimpling and systole.

S. 4. No auricular sound could be distinguished, apparently less attributable to want of energy in the auricle than to the rapid beat of the heart and sudden supervention of the ventricular systole before the completion of the auricular. The left appendix

was repeatedly inverted with a pencil and with the finger, and on the instant of being let free, by withdrawal of the pencil, &c., recovered its shape and position, appearing to emerge with rapidity out of the auri-ventricular orifice and sinus, apparently owing to a continuous and copious influx of venous blood into the appendix, especially during the systole of the ventricles.

S. 5. In experiments on the mitral valves, repetitions of former trials, and with inverted auricles, some resistance, as of a hard edge, was repeatedly felt by the finger, and the pencil was pushed outwards with some force, but the edge felt was suspected to be the edge of the interior orifice and not that of a valve. On the inner side, or that next the septum, the resistance in systole was more energetic than on the outer.

S. 6. The thread that had been passed through the appendix was drawn upwards, to check the systole of the auricle during auscultation, but the operation was with difficulty performed, and at all events no perceptible difference resulted; the first cardiac sound appeared unchanged.

S. 7. A slight motion of the cava was observed accompanying the auricular systole, viz. a diastole followed by a systole; both slight.

S. 8. In systole the ventricle became rounder, harder, tenser, and shorter; both fundus and apex, but especially the latter, were seen to be elevated, and the apex seemed to turn slightly from left to right.

S. 9. An eccentric impulse, or abrupt push outwards, was perceived on whatever part of the ventricle we touched, while the heart acted with any energy; and this push or impulse was most striking, though least powerful, just at the apex, on account, as it seemed, of its pointed form.

S. 10. An undulatory sort of motion was perceived in systole from fundus to apex, along the parietes. In addition to the general eccentric impulse, there was observed over the orifices, arterial and auricular, a jerking motion not observed elsewhere; and this jerking was indistinct or null over the interior orifice, in a subsequent experiment, in which the mitral valves were prevented from closing by a slender instrument something like scissors, the parts of which beyond the joint were introduced, through the auricle, without inverting it, into the auri-ventricular opening; and while the blades were kept separate, the first sound, as heard on the ventricles, was found to begin dull and obtuse; and an obtuse beginning, and a well-defined beginning were heard alternately, according as

the blades were separated or brought together, and as consequently the valves were obstructed or left free.

S. 11. The tip of the left auricle was snipped off and hæmorrhage was excited, which was constant but with slight jets at the systoles of the auricles.

Observations IX. and X.

July 7th.—Operated on two Rabbits; one a large vigorous domestic one, and the other a smaller wild one; both stunned by a blow on the head. The larger one was violently convulsed before death, and when the chest was opened the heart was not beating, and the only result obtained was—

S. 1. Distinct beatings in the large vein on the left side which winds round the base of the heart to empty itself in the right auricle; the actions observed were a systole followed by a diastole, and then a short pause; there was no auricular systole; the venous beating continued for many minutes.

S. 2. The second heart acted for some minutes with some energy, especially the right cavities; the left cavities were drained by hæmorrhage, owing to an accidental wound in the superior great vein in opening the thorax. For some minutes the rhythm of the action of the cavities went on normally; first, the very rapid and abrupt auricular systole, and then immediately the ventricular systole more gradual and of longer duration, and then the pause.

S. 3. When the left ventricle acted, the apex cordis seemed slightly deflected to the left in systole, dragging the apex of the right after it; and when the right ventricle acted alone, no deflection was observed.

S. 4. For a considerable time after the cessation of the left side, the right cavities acted regularly, but after five to ten minutes, the ventricle especially began to flag, and the auricle then acted frequently without any following ventricular systole. But on one occasion, without obvious cause, the auricle became sluggish, and even for a few moments motionless, while the ventricle acted by itself more than once.

S. 5. In the systole, the apex approached the base, and the opposite sides approached the septum cordis, and the whole organ became rounder and more globular. In one direction, viz. the vertical, the heart always, when acting with any energy, became larger, while every other diameter was diminished.

S. 6. After cutting out the heart, and before cutting out, but after cessation of spontaneous motion, systole was easily excited by irritating with scissors, etc., and after the left had nearly wholly ceased to answer stimuli, still the right ventricle

contracted on the point of a scalpel being applied to the left ventricle.

Observations XI. and XII.

July 11.—*Phænomena: Stroke and sound obtained as if from locomotive force in systole of ventricles;—rhythm of the heart's motions;—manner of auricular action;—same of the ventricular-venous motions;—mechanism of the cardiac throb or impulse;—mode of hæmorrhage from a wounded auricle.*

Subjects, two Donkeys operated on; one about six weeks old, the other about two and a half months; both rather weak from fasting twenty-four hours, owing to being too young to eat or drink properly. Each heart ceased to beat after about half an hour. First animal had his forehead beaten in so as to stun him, and chest then opened. Heart acted quickly and not very regularly. No distinct second sound; no auricular sound.

S. 1. Before opening pericardium, a hard flat body, having a piece of lead weighing about a quarter of a pound fixed on it, was placed on the heart, and a stethoscope was held at a short distance over it, *i. e.* at a quarter to half an inch, and at each systole of the heart the lead rose up abruptly and struck the stethoscope with a tick, audible at some yards distance, and receded with diastole to sometimes nearly half an inch, and again rose up and impinged on the tube in systole, and so on.

S. 2. The pericardium was then opened, and the auricles and ventricles observed. No auricular sound could be detected. The auricles acted immediately before the ventricles, and after the pause or rest, and very abruptly and rapidly: the heart acted rapidly, probably considerably above one hundred per minute.

S. 3. The auricles were observed in systole to dimple and contract all round from periphery to centre, as in former observations.

S. 4. The changes of shape in the ventricles were particularly plain and striking—the apex moved slightly upwards and to the left, and was drawn toward the base in systole, while the horizontal transverse diameter of the heart, as the animal lay on its right side, was diminished, and the transverse vertical diameter, and that alone, was increased, owing to the heart becoming from flattish, inferiorly and superiorly, convex, and from in the centre compressed or depressed, strictly globular or protruding, so that the central longitudinal axis was elevated during systole, and lowered in diastole, while in diastole the apex rather approached the sternum from which it had receded in systole, owing to shortening of the organ.

S. 5. The veins were observed, and except perhaps a slight

undulation downwards during auricular systole evinced by a diastole followed by a systole, both very slight, nothing decided was observed. As in all former observations the ventricles and auricles respectively acted together.

Observation XII.

The second and older animal was prepared by injection of woorara, and, after establishment of artificial breathing, the left ribs were cut quite close to the mesial plane, so as to expose fully the apex in every motion.

(*Note.*—The former was opened in the same way and with the same effect.) The pericardium was then opened, and the following results were obtained.

S. 1. The hard substance (sole leather) weighted with lead, was applied to the heart, and the same result as in the former experiment obtained, viz., a sudden abrupt elevation or jerk upwards of the lead was obtained, and a stroke against the stethoscope heard distinctly at several yards, and the range of oscillation or motion of the lead was about half an inch.

S. 2. On opening the pericardium the auricles and ventricles were acting as in the former observation, viz., the auricles first after the rest or pause, and the ventricles immediately after the auricles. No auricular sound was detectible; no distinct second sound heard. Heart acting hurriedly and with varying quickness, but always above the healthy standard.

S. 3. The motions of the ventricle very conspicuous, and as in last observation, viz., striking diminution of horizontal transverse and of longitudinal diameters, and increase of transverse vertical diameter in systole, and in diastole increase of the two former diameters, and decrease of the last. And in systole the apex was raised, as was the whole body of heart, by an elevation of the central longitudinal axis, which was effected partly by the assumption of a globular form in the previously compressed central inferior surface, and partly by the visible protrusion of the previously depressed central superior surface of the ventricles.

So long as this observation lasted both auricles seemed to act with equal pertinacity; the right auricle being however snipped, and long after the ventricles had ceased, the blood gushed out of the right auricle only when the auricle contracted, and the hæmorrhage ceased nearly during the diastole of the auricles.

S. 5. No other appearances observed in the veins than in the former experiment, viz., a slight diastole with the auricular systole followed by a systole with auricular diastole.

S. 6. In neither of the two preceding observations did the auricles and ventricles exactly alternate, but in each, whenever observation was carefully made, the auricular systole immediately preceded the ventricular; and the ventricular diastole preceded the pause or rest, which last was first interrupted by the abrupt auricular contraction.

Observations XIII. and XIV.

July 15th.—Subjects, a Donkey (about a twelvemonth old, prepared with woorara; very little blood lost in opening; animal not healthy, and weak, so as to be ill able to walk before the operation; heart acted pretty well)—and a Dog.

Phænomena: Donkey—Rhythm of motions;—character of auricular actions;—same, of the ventricular;—double friction between heart and pericardium normally;—eccentric impulse felt all over ventricles in systole;—motions of cava.

Phænomena: Dog—Normal double frictions of pericardium;—with other phænomena.

S. 1. Rhythm of motions of the auricles and ventricles was as in former experiments; first, the auricular systole, then immediately, the ventricular systole, without interval, and as if it were a continuation by undulation of the former motion.

S. 2. Then the pause during which the auricle and ventricle became each distended and soft and flaccid, the former sliding its extreme margin downwards on the fundus of the ventricle toward the apex, to retract it suddenly again toward the sinus in systole,—and the latter protruding its apex and sides so as to be enlarged in every direction, except that of the transverse vertical diameter, to retract both apex and sides in the following systole, and at the same to rise upwards in its central parts with an impulse.

S. 3. Before opening pericardium the condition of that sac was carefully observed, and it was noted, that while the pericardium remained stationary under all circumstances, the heart suffered much change in shape and size, so that there was in every part, and especially over the auricles, a to-and-fro motion of the cardiac pericardium on the external layer of that sac, a friction in one direction in systole and in the opposite in diastole.

S. 4. The impulse before observed was obtained by the finger applied to any part of the ventricle in systole.

S. 5. The cava observed, and a slight action was noted, viz. a diastole followed by a systole, the former with a wave-like sensation of motion from the heart downwards, and accompanying the auricular systole, and immediately preceding the ventricular. The separator above described was introduced into

the mitral aperture and a murmur was heard; but the heart ceased too soon, owing to errors in the insufflation, to allow of the experiment being properly followed out.

Observation XIV.

Same day. A Dog, small, and perhaps two years old, was poisoned with prussic acid, and then prepared as usual. The heart acted pretty well for nearly half an hour.

S. 1. The stillness or inertness of the free pericardium and constant succession of changes of shape and size in the heart were carefully observed; the heart being, for the size of the animal, much larger than that of a donkey; the experiment was much less troublesome from that cause as well as from the greater facility of manipulation of a smaller animal. Every systole of the auricles produced a double friction, viz., one against the external layer of the pericardium and one against the fundus of the ventricles, or periphery of the auricular orifices; and every diastole of course produced friction in the opposite directions; and every systole of ventricle produced friction longitudinally from apex to fundus, and transversely from side to side, all round the body of the heart; while every ventricular diastole included friction in the opposite directions.

S. 2. The rhythm of the heart's motions was as before, viz., first, the auricular systole,—and secondly, immediately thereafter, the ventricular, and without marked interval, but, as if the latter motion were but a continuation of the former, by a sort of continued undulation,—and thirdly, the pause consisting first of auricular diastole, and then including the immediately succeeding ventricular diastole, and interrupted first by the auricular systole.

S. 3. Cava observed and motion noted, viz., a diastole followed by a systole, the former synchronous with the auricular systole, the latter immediately following.

S. 4. The subclavian artery laid bare unintentionally for several inches, forming an arch more than two inches in length, and observed to lengthen without straightening in the systole of the heart, and to shorten slightly but sensibly in ventricular diastole.

S. 5. As in every former distinct observation, the sensation of impulse was perceptible on every portion of the ventricular surface; the shortening, rounding, hardening, and elevation of the central longitudinal axis, and increase of the transverse vertical diameter alone, of the body of the heart, easily distinguished,—also the jerking over the orifices, &c., &c.

S. 6. The auricular systole apparently audible, but the sound

not separated by any very distinct interval from the instantly succeeding ventricular sound, which however it preceded rather, and certainly preceded to the senses of touch and hearing together, the hardening and rounding of the ventricle.

S. 7. In the dog, as in the ass, the motions were slow comparatively in the heart, auricles as well as ventricles. The right ventricle first, and afterwards the left ventricle, were punctured with a slender glass tube drawn out for a couple of inches at the lower end, and the result observed. In systole there was a sudden rise in the tube, and a slight subsidence in diastole. The subsidence was but slight, the greatest not being in the left ventricle more than half an inch, and in the right ventricle still less. The sinking of the blood in the tube in diastole was such as might be caused by a sudden withdrawal of an impulse sufficiently energetic (like that of the systole) to overcome gravitation abruptly, and so as to excite a jet in a tube containing a fluid column sustained by a constant pressure (such perhaps as might be produced by the venous influx) from below.

S. 8. In both hearts the right cavities were relieved from distension before complete cessation of action, and the areas of the ventricles, judging by apparent extent of walls opened and spread out, seemed in no degree to differ.

Observations XV. and XVI.

July 18th.—Operated on two Donkeys of from four to eight months old.

Phænomena : First donkey—Glass tubes introduced into left auricle and ventricle, and results noted ;—normal pericardial frictions observed, and several other observations confirmed : Second donkey—Blunt hook and screw, successively interposed between mitral valves with considerable modification of first sound ;—also, spontaneous abnormal sounds ;—auricular systolic sound ;—results of introduction of glass tubes into heart's cavities ;—confirmation of former observations.

Woorara injected in each case ; in the first, the operation very successful, but in the second, a second dose of two grains required.

In the former, much blood lost, viz., probably owing to an accidental cut made in hastily opening the trachea for artificial breathing. The heart found acting rapidly, hurriedly, and with a rhythm unfavourable for observation. Second sound not distinct. The experiments intended were two, viz., stopping the mitral valves by an interposed blunt hook introduced through auricle, or by a screw-shaped wire similarly admitted; but owing probably to profuse hæmorrhage, the first sound was not suf-

ficiently normal for that experiment, and the second experiment was made, viz.—

S. 1. Glass tubes drawn out at one extremity were pushed, with a rapid rotatory motion, into the auricle and ventricle of left side, and the column of blood observed. That in the auricle gave no satisfactory result, owing to sanguineous exhaustion apparently, and the consequent insufficient distension in diastole, and slight amount of contraction in systole in the auricle. But this much was noted, viz., that a very short column that filled the drawn out part, was not drawn in diastole, yet neither was it very strikingly lengthened in systole. The ventricle gave better results, viz., a column rose rapidly by successive stages, rising some lines at each systole, and continuing almost stationary at each succeeding diastole, and at length overflowing the tube and pouring over in large drops at each systole.

S. 2. The friction between the heart and pericardium in systole and diastole of auricles and ventricles; the tension and jerking motion upwards in systole; and softening and subsidence in diastole of the parietes of the ventricles; the abrupt jerking over the orifices in systole, followed by subsidence in diastole; the shortening of the diameters lengthwise, and transversely in systole; the immediate succession as by a continued undulatory motion of the ventricular systole to that of the auricles; the sensation of an undulation from fundus to apex on the ventricles; the dimpling in systole of the left auricle (which only was observed); and the equality, post mortem cordis, of the two ventricles;—all those former observations were repeated, and former results confirmed.

Observation XVI.

S. 1. The second animal's heart when exposed was acting with more regularity than the former, and the blunt hook and screw were successively tried. In each case material modifications of the first sound were repeatedly produced by the interposition of the instrument between the valves in left interior opening; but the modifications were not constant: and in no case was there any attempt made to impede the right interior valves. This much however was noted, that on several occasions the interposition of the instrument was followed by murmur in the mitral opening with the systole, and by a more obtuse character of the first sound, and particularly by a want of sharpness of definition at its commencement. But it is to be added, that considerable irregularity existed for the greater part of the time in the sounds, viz., the first sound seemed

sometimes, and without apparent cause, more obtuse than others, and more short and abrupt, and the second was often wholly wanting or too indistinct for observation.

S. 2. Further, there was observed a feeble dull sound, very short and rapid, synchronous with the left auricular systole, and somewhat anterior to the ventricular hardening, and uprising, but scarcely separated by any distinct interval from the ventricular sound, and rather continued into it in a manner resembling the apparent passage of the auricular systole into that of the ventricle.

S. 3. The glass tubes were in this experiment introduced as before, with similar results. Nothing striking occurred in that passed into the auricle, but a very short column being obtained, and that nearly stationary, owing probably to the auricle having been penetrated in several places by the hook and screw so as to suffer escape more readily by the other orifices. But the ventricle gave like results as in the former case, viz. a column rising in systole, stationary in diastole, and at length reaching the upper end so as to overflow. All the previously observed phænomena of the motions of the auricles and ventricles, in themselves and with respect to each other, and with respect to the pericardium, were confirmed on this subject, so that the description of those given under the head of the former experiment of this day, themselves but repetitions of former observations, must be considered to apply to the normal condition without any important restriction or qualification.

Observation XVII.

July 26th.—*Phænomena: Dog—Distension to hardness of auricles during a torpid and as it were semi-paralytic state of ventricles;—results of a prick in left auricle;—proofs of active nature of auricular systole, and of negative character of ventricular and auricular diastole;—of venous regurgitation during auricular systole, and of equal size of both ventricles, &c.;—confirmation of other former observations.*

Subject, a Mastiff-terrier eighteen months old, poisoned—with prussic acid.

S. 1. Heart acting regularly but rather feebly, though large and muscular; much distended and on both sides equally. Left ventricle and auricle both much dilated and the auricle quite tense with blood, so that the appendix could not contract for some time until a prick was made in it, when a jet was observed coincident with the systole. Some observers thought the jet synchronous with the systole of the ventricle; but on placing the fingers in contact with the sinus and fundus ven-

triculorum together, it was plain that the jet coincided with the auricular systole, and preceded by a fraction of a second the ventricular systole. During the diastole of the auricles a slight shortening of the column, as from diminished impetus from below, occurred, and again, in auricular systole, a sudden lengthening of the column, to be followed again by a shortening in diastole.

During the systole of the ventricles immediately succeeding that of the auricles, and without distinct interval, no increase of the jet or column occurred, and during the diastole of the ventricles no subsidence, but simply a shortening, as before described, immediately after the auricular systole.

During great part of observation of the jet the left auricle was tense and hard almost to the finger, and nearly immoveable, and the ventricular action was dull and feeble, and the ventricles themselves were not fully emptied in systole, the heart appearing to have suffered considerable torpefaction from the poison.

S. 2. A glass tube was introduced into the left auricle and ventricle in succession, but a clot soon forming, owing to escape of soda solution during the rotatory motion by which the glass was first introduced, no very decided result was obtained.

S. 3. After the ventricles had become very feeble and even the left auricle become comparatively inert, some energy of contraction was observed in the right sinus, and with each contraction a wave of regurgitation down the vena cava inferior, viz. a diastole of the vein immediately preceding the ventricular contraction and coinciding nearly with that of the auricle, and followed by a systole coinciding with ventricular contraction and auricular diastole. The auricles at no time acted with sufficient energy to promise any result from traction by a string, or to yield distinct sound in systole, owing to an extreme distension of the cavities, attributable to torpor of the muscular substance and rapid and copious supply of blood from the veins.

S. 4. The ventricles after death seemed not to differ materially in size, having been cut out before complete death, and allowed to contract.

S. 5. Several previous observations confirmed on this occasion, viz. as to rhythm of motions and cavities; viz. auricles and ventricles respectively acted exactly together, and the former immediately before the latter, and without distinct interval, but as by continued undulatory motion; elevation of central parts of ventricles in systole and subsidence in diastole; frictions of the pericardium double with each pair of cavities, viz. both in systole and diastole.

Observation XVIII.

Phænomena: Tubes introduced into heart's cavities; results; —confirmations of former observations as to rhythm, pericardial frictions, changes of shape in the heart, &c., &c.; comparative sizes of ventricles.

July 30th.—Operated on a Dog between one and two years old by prussic acid. Heart acting feebly, with the normal rhythm however; the cavities considerably dilated.

S. 1. Glass tubes containing strong solution of carbonate of soda, secured during the introduction by corks temporarily fixed in the wide end, were introduced by a rapid rotatory motion into the right ventricle and auricle. Owing apparently to awkwardness in the manipulation, the result was not throughout uniform to the eye; but the general character of what was observed was this: Columns of blood rose into the tubes in every case, and were perceived to overflow in each case with a slight jet in the systole of the cavity penetrated, and a slight subsidence in the diastole. At one time, for a minute or two, without interruption, the tubes were observed to overflow steadily together, one being in left auricle and the other in right ventricle, each having a slight jet, or upward undulation, in the systole of the cavity containing it. This experiment was comparatively very striking, owing to the great difference in colour of the two streams, viz. scarlet, and deep crimson or purple.

During the whole observation nothing occurred suggestive of impulse, except of the impulse upwards of the systoles of cavities, and the slight gravitation or subsidence in diastole; and this latter, though often very distinct in each tube, was sometimes quite imperceptible in either. No motion downwards in the tubes, such as suction would explain, was observed.

S. 2. After the observation the heart was cut out, and the left ventricle appeared rather larger than the right.

S. 3. The rhythm of the motions of the cavities; the auricular and ventricular double frictions of the pericardium; the jerking upwards of the fundus and central parts of the ventricles in systole; the shortening in systole; the stationary state of the heart amid all its changes of size and shape; the subsidence of the central parts and fundus in diastole, &c., &c., were noted to agree with former observations.

Observations XIX. and XX.

Aug. 5.—Operated by woorara on a Donkey two or three years old. Operation tedious, owing to strength and resistance of the animal. Also on a Dog.

Phænomena: Donkey—Negative character of diastole.

Dog—Apex cordis threaded and held tense in the direction of the mesial plane of the subject. Results: change of shape and size of the heart in systole and diastole, and visible motions;—glass tube passes into cava inferior; results;—columnæ carneæ and parietes electrified; results;—cavities compared post mortem and found equal.

S. 1. Glass tubes introduced into the left ventricle at fundus and apex, and in each a column rose and at length overflowed, having a slight subsidence at each diastole, and sudden elevation at each systole; but no well-marked difference between the times of rise and fall in the tubes was detected.

S. 2. The heart acted for some time with considerable energy, notwithstanding great hæmorrhage, but soon failed after being perforated. The heart was then cut out while yet contracting vermicularly, and electricity was applied so as to permeate the columnæ and parietes, but no satisfactory action was obtained. The cavities of the heart had been for some time much distended, from loss of irritability before excision.

Observation XX.

A Terrier-dog, stout though small, was then stunned by a blow on the head; the chest was rapidly opened, and artificial breathing established.

S. 1. The apex cordis was then threaded, and at each systole a pull at the chord was observed, followed by relaxation, and the tension and relaxation of the string alternated; the former coinciding with systole, and the latter with diastole.

(*Note.*—The string was drawn in the line of the longitudinal axis of the heart.) Dr. Boyd at one time kept the string firmly extended and permanently tense, by holding his hand as far away as the string would allow, for a short space, and then maintaining his position, but relaxing his hold so as to allow the string liberty to slide between his fingers when drawn away; and the result was, that before the experiment was suspended, an inch or more of the string appeared to have passed between his fingers, one eighth of an inch at least being pulled through at each systole.

S. 2. After this observation had been made and repeated to the satisfaction of all parties, the heart acted still with much vigour, and both sounds were distinctly audible, notwithstanding great loss of blood. Also the diminution of the horizontal transverse and of the longitudinal diameter, and the increase of the vertical transverse diameter, with sudden bulging upwards of the fundus and central parts, were very plain to the

eye in systole;—while in diastole the subsidence of the central parts, with sudden increase of the horizontal cross diameter and of the long diameter, were equally striking. No tilting of the apex as an independent part was noted, nor any other motion than such as might be explained fully by the fixity of the fundus through the vessels, and the sudden increase of the cross vertical diameter in systole, causing an elevation of the longitudinal or central axis, which was most sensible at the apex or free extremity.

S. 3. A glass tube was introduced into the cava with the termination directed towards the diaphragm, when a column of blood rose gradually without any jet until it reached the upper end nearly, when it ceased to advance, but continued stationary for some time, and at length receded slowly towards the middle of the tube. No sudden motion either upwards (as *ex. gr.* by auricular contraction) or downwards (as by diastolic suction) was observed. A gradual partial subsidence in the tube then followed, owing apparently to failure of impulsive force in the moving powers of the venous circulation.

S. 4. The heart was then cut out while yet contractile, and irritated by electro-magnetism and by pricking with scalpel, and to the satisfaction of every one present the columnæ carneæ were observed to contract and relax coincidently with the parietes.

S. 5. The ventricles were equal in capacity to the eye and hand post mortem cordis.

Observations XXI. and XXII.

August 8.—Two Dogs operated on; one a stout terrier, the other a mongrel bitch, both eighteen months to two years old.

Phænomena: Second dog—Glass tube introduced into cava; results variable, with probable causations of fluctuation;—auricles cease action first;—columnæ carneæ irritated alternately with neighbouring parts of parietes, and results;—confirmation of former observations respecting the mechanism of heart's action and the equality of the cavities during life.

In the former animal the operation failed, owing to not having established artificial breathing in time.

In the dog the following results were obtained. Having been prepared by stunning and tracheotomy, with a view to artificial respiration, the heart was exposed, and found beating with energy, exhibiting the usual motions and sounds.

S. 1. A curved glass tube was introduced into the cava inferior, and immediately a column of blood was observed, which, after ascending some way steadily, and during several beats of the

heart, again descended also steadily and during several beats. After a few moments, the tube being held upright with care, and the lower opening of the tube being toward the abdomen, and pressure being made on the tube through the parietes of the veins, a column of blood ascended slowly and steadily to the top of the tube and poured over at the top. Again, pressure being withdrawn from the cava, fluctuation occurred, viz. irregular ascents and descents of the column, gradual and slow, and extending each of them over several beats of the heart, there being perhaps as many as half a dozen of each to each minute of the time they lasted. At no time was there any sudden elevation or subsidence of the column, such as the auricular systole or ventricular diastole might be supposed to produce, supposing the latter to include suction towards the ventricles. The variations of level observed in the tube could be referred with any probability to nothing obvious, except the convulsive agitation of the right thorax, which was intact, and which heaved and collapsed violently for a short time, owing to a partial recovery of the animal from the stunning blow during the operation, in consequence of hæmorrhage and artificially sustained breathing. The tube was then introduced into the cava superior, and a column was observed in the whole length of the narrow part of the tube, and nearly an inch in height, and this column suffered no alteration either in systole or diastole. The shortness of the column in this case was owing obviously to exhaustion of the vascular system, or insufficiency of blood and of vascular tension. There was not any respiratory effort during this last observation.

S. 2. During this last observation (on the cava superior) the unusual appearance was observed of complete quiescence nearly of the auricles, whilst the ventricles continued to act with considerable energy. The early death of the right auricle might be referred to withdrawal of supplies from the cava inferior especially; but that of the left auricle is not easily accounted for, since insufflation was duly persevered in.

S. 3. The heart was cut out while yet contractile, and the columnæ carneæ of the right ventricle were observed to act accurately with the parietes, whether the stimulus were applied to the former or latter only. The columnæ of the left ventricle were become insensible to stimuli, and the parietes nearly so before the left was laid open for observation.

S. 4. The elevation of the central cardiac axis, and especially of its free extremity, viz. the apex cordis, was very conspicuous in systole, and the opposite motions in diastole. Also the flattening and lengthening of the ventricles in diastole, and

rounding and shortening in systole. And after opening the ventricles the left seemed the larger of the two.

The wave-like motion, or sensation as of an undulation from fundus to apex in systole, was very distinct.

Observation XXIII.

August 24.—A Dog (bull-dog terrier), one to two years old, stunned, and chest artificially inflated.

Phænomena : Results of threading different parts of the ventricles, and at the same moment pressing the threaded parts with the finger, and pulling at them by means of the thread, showing the mechanism of the heart's throb ;—rhythm of cardiac and aortic pulsations ;—results of introducing a tube into the cava ;—respiratory suction ;—venous regurgitation in systole ; —phænomena of the heart's action out of the body both as to motions and sounds.

S. 1. The heart was laid bare and a thread was passed through the apex cordis, and a second through the parietes nearly over the mitral orifice, and traction was exerted on each string in a direction outwards, and away from or vertical to the point of insertion, and the result was that in each systole each string was felt to be pulled and rendered tense, and to become lax in diastole. At the moment of tension in each chord the finger was placed on the point at which each respectively had been introduced, and the result was a double sensation, viz. 1. That of traction in the chord, indicating contraction of the heart and mutual approximations of its extremities, and, 2. that of outward impulse in the point of the parietes under the finger (indicating, as the Reporter conceived, the undulation of the blood reacting against the compressing parietes of the ventricles).

S. 2. The attachments of the vessels or muscular parts inserted into the roots of the arteries, especially the pulmonary artery, were observed very distinctly to approximate slightly towards the apex in each systole, and to recede from the apex in diastole.

S. 3. A barely perceptible difference in time was detected between the systole of the left ventricle and diastole of the aorta—no distinct interval however.

S. 4. A glass tube was introduced into the lower cava, and a column of blood obtained, which oscillated frequently, but not in accordance with the heart's motions. These oscillations were attributable (the Reporter conceived) to irregular, spasmodic, respiratory efforts, occurring in the right side of the chest, which was still air-tight, the mediastinum being still

intact. The oscillations were sometimes short, and rapidly succeeded to each other with a rhythm not differing greatly from that of the heart, but at other times were protracted through several beats of the heart, viz. an ascent continued for several seconds successively, followed by a descent in the tube of similar duration.

S. 5. The pulsation of the veins was very distinct to the eye in systole, in both the pulmonary veins and cava; but whether owing to the auricular systole exclusively, was not examined into with sufficient care. This much was ascertained, that the visible venous action was a diastole coinciding with the commencement of the general action of the heart, and followed immediately by a systole. Neither diastole nor systole of vein seemed gradual, but abrupt and almost instantaneous.

S. 6. A heavy curved knife was placed on the left ventricle and held erect between the fingers, so as to allow motion upwards or downwards, and the result was as in former experiments, an elevation by sudden heave upwards of the knife in systole, followed by a subsidence in diastole with depression of the surface.

S. 7. The heart was cut out while still beating, and continued to beat in the hand regularly, with normal rhythm, for a minute or two, and notwithstanding being shifted from hand to hand amongst three observers. The first sound was very distinct during the whole of the time, but less sharply defined at the commencement. It wanted likewise the jerking motion over the auri-ventricular openings, and the strong eccentric impulse or upward heaving in systole, and strongly-marked subsidence of the ventricle in diastole. The concentric motions and general rounding and shortening in diastole were very distinct. There was no second or diastolic sound. When cut open, the columnæ carneæ were seen to act along with the parietes.

Observation XXIV.

August 26 and 28.—Repeated the experiment on the contraction of the abdominal muscles, as productive of a sound resembling the systolic sound of the heart, in the presence of Dr. Edwin Harrison, Dr. Hamilton Roe, Mr. Phillips, F.R.S., Mr. Gulliver, F.R.S., and Dr. Robert Boyd.

The instrument employed was the flexible ear-tube or stethoscope, with which only the experiment is satisfactorily practicable, on account of the strong impulse attending the contraction, and the difficulty of distinguishing the acoustic from the tactual sensations it occasions.

The end of the instrument was placed in mediate contact with the abdominal parietes, and held firmly down upon the surface, with the intervention of a shirt and thick flannel under-vest; a strong and sudden expiratory effort was then made (in the manner described in the First Report of the London Committee) with the mouth and nostrils closed, so that a strong vibratory action, ending in firm tension of parietal muscles, was sensible to the subject of observation (the Reporter), and likewise to the observers, and with this result, that a single loud, obtuse, abrupt, short sound was heard, and thought by every gentleman to resemble, more or less, the systolic sound of the heart.

S. 2. The same experiment was repeated, with the addition of several folds of a silk handkerchief to the intervening substances; and again, with a double fold of cloth and silk likewise, in addition to the under-clothing above named, but without any important difference of result.

S. 3. Hard substances also were interposed above the under-clothing, viz. a common framed school slate, and small bound books of different sizes; but no important difference was observed, except with the slate, through which the sound was considered to be decidedly less distinct than in any other form in which the experiment had been tried. In all these trials pains were taken to keep the cup of the stethoscope in accurate contact all round, through the substances interposed with the abdomen; and that was easily effected by the use on the part of the Reporter, who was the subject of experiment, of both hands at once in maintaining equable pressure.

It is proper to mention, that several observers agreed in stating that similar sounds occurring to show in the cardiac region, would be referred by them to the systole of the heart without any hesitation.

Conclusions from both Series for 1838–39 and 1839–40.

Motions.

1st. That the order of the motions of the auricles and ventricles is by *continuous succession* rather than by *alternation* of actions. The auricles contract abruptly after the Rest or pause, and the ventricles immediately after the auricles, without any distinct interval between the successive systoles. And the diastoles of the cavities follow in somewhat similar

order, viz. the auricular diastole coinciding with the ventricular systole, and continuing after it; the true Rest or pause being constituted by the diastole of the auricles and ventricles together, and in reality ceasing on the recurrence of the auricular systole. This rhythm of the motions seems to be universal and common to cold- and warm-blooded animals. The only exception known to the Reporter from books or observation, seems apparent rather than real, viz. an alternation of action, such as noted by Lancisi, for example, in the chick *in ovo*, and by several observers in cases of very rapid cardiac action. In such cases the diastoles have been so hurried and short, (owing no doubt to very rapid and copious influx from the veins,) that the systoles have been approximated to each other, and the intervening Rests have been apparently suppressed, and an apparent true alternation of systoles and diastoles without intervening Rest has been produced.

2nd. That the visible systolic and diastolic motions are first perceived at the bases or fixed parts of the cavities, viz. in the auricles at the sinuses, and in the ventricles at the fundus cordis; and that the apices of the auricles and ventricles (or free parts) are brought into full action after the other parts, and only just before the supervention of the opposite and next succeeding condition of the cavities, whether that condition be systole or diastole.

3rd. That in systole the heart is diminished in all directions (except only in such regions, or parts of the organ, as may have been previously collapsed or compressed during the unresisting flaccidity of the diastole), and that its long axis in particular is strikingly and invariably shortened.

4th. That the normal systole of the auricles is energetic and almost instantaneous, and quite universal, the manifestations of contraction in the appendix succeeding to those of contraction in the sinus, by a very minute interval; and that the auricular diastole is gradual, continuous, and wholly passive, and is effected by an influx of blood from the cava progressively distending the cavity from sinus to apex, and from the termination of one systole of the cavity to the commencement of the succeeding one.

5th. That the systole of the ventricles is gradual in its development, and complex in its phænomena; that those phænomena are partly attributable to contraction in the muscular parietes, and partly to resistance on the part of the fluids. By the muscular contraction the heart is made to compress the blood, which resists in all directions alike, and thrusts out

the depressed or collapsed parts of the ventricles, and favours the systolic shortening of the organ, and the closure of the auri-ventricular valves; and this reaction of the fluids mainly contributes, under various circumstances, to cause the motion that has been described as tilting of the apex; this tilting being principally, if not exclusively, a result of the elevation of the long axis of the heart in systole, owing to the assumption of a convex or globular form in the body of the organ, instead of its superiorly and inferiorly compressed state in the previous diastole.

And the ventricular diastole or dilatation is wholly passive, exerting no influence over the venous current or arterial valves, and is effected by a rapid influx of blood from the veins, commencing at the moment of relaxation of the ventricles, and continuing until their succeeding systole, and reinforced immediately before the latter action by an abrupt discharge from the auricles.

6th. That the pulsations of the veins are of two kinds, at least in some animals, viz. both active and passive; and the latter or passive pulsations (which, on the authority of Haller especially, may be held to exist in all animals), are attributable to reflux from the auricles in their systole.

7th. The præcordial throb or pulsation is caused, immediately, by the undulation of the blood in its resistance to sudden muscular compression in the systole of the ventricles. This reaction of the fluids is first perceived about the fundus of the ventricles, and last about the apex, towards which it seems to be propagated by a continuous undulation from the fundus with extreme rapidity. In consequence of this reaction of the blood, the heart's sides are rendered convex, instead of compressed or flattened as in diastole, and are, in the middle parts more especially, heaved outwards from the central axis abruptly and with great force. Thus on all parts of the surface of the organ an impulse is felt in systole, which is greatest there, where, in addition to passive flaccidity of walls, there has been collapse in the diastole (viz. the central parts), and which is least where such collapse has previously been wanting or slight (viz. the apex). This cardiac impulse is usually perceived, in the healthy subject, over the apex only, owing to its being absorbed and neutralized over other parts of the heart by an interposed thick mass of spongy lung. The heart does not oscillate on the aorta, or move to and fro in the chest from systole to diastole, and *vice versâ*; nor does it suffer any changes in consequence of its own efforts, and exclusively of movements of the lungs and dia-

phragm, excepting in its shape and size, and in the thickness and tension of its parietes, and the capacities of its cavities. The doctrine, that the præcordial pulsation is caused by a blow received by the ribs, in consequence of the heart's "jumping" (*ἅλμα*, Hippocrates) or "striking" against them (" pectus ferit," Harvey; " costam ictu percutit," Haller, &c. &c.), appears to be superfluous, with a view to explanation of phænomena (notwithstanding the ingenious illustrations of the ancient opinion by Senac and Hunter), and to be substantially unfounded in point of fact.

8th. That the arterial diastole or pulse, almost everywhere outside of the pericardium, perceptibly succeeds to the cardiac systole; though near the heart, the interval between them is very brief, and to unpractised observers difficult to distinguish.

Sounds.

9th. That the first sound of the heart depends partly, but in a slight degree, on the abrupt closure and transitory tension of the auri-ventricular valves, which give to this sound its sharp, well-defined beginning; but that the first sound is mainly attributable to *cardiac muscular tension alone*, and that its prolonged duration is probably owing to the progressive character of the normal systolic effort from fundus to apex; and that this sound is probably, in no degree or condition, attributable to any blow or stroke of the heart against the ribs.

10th. That the auricular systole is attended by an intrinsic sound resembling that of the ventricles, but more short, obtuse, and feeble. This auricular systolic sound is often difficult of detection, even on the naked heart, and with tolerably vigorous action of the auricles, owing to its being, to the inexperienced ear, absorbed in, or masked by, the immediately-succeeding and vastly louder systolic ventricular sound.

11th. That the sounds of friction in pericarditis may, where well marked and under ordinary circumstances, be expected to be double at least, and they may be, not improbably, triple or more. In its systole, each cavity of the heart moves so as to cause a friction, in one direction, of its attached lamina against the adjacent free lamina of the pericardium; and in its diastole, a pericardial friction is caused by each cavity in an opposite direction; and as the auricles move to and fro independently of the ventricles, the normal pericardial frictions must be quadruple, or double with the auricles and double with the ventricles. If, therefore, those frictions were ren-

dered sonorous by the interposition of any rough substance between the rubbing surfaces, (as lymph, for example,) and supposing the heart's actions sufficiently vigorous, under ordinary circumstances, we might anticipate with confidence a duplication of murmurs at least—one systolic and one diastolic; and this must be the principal element in the acoustic diagnosis of pericarditis, since effused lymph may be of any thickness, consistence, extent, &c., and be situate on any portion of the heart's surface between its nearest part and its furthest; and may therefore cause friction-sounds of the most variable seat, depth, and character. But, of course, another physical means of distinction of great importance remains, viz. the comparatively equable diffusion of the sounds of pericardial friction all around the place of attrition, rather than in any one exclusive direction.

12th. The sounds of the structurally-healthy heart are much liable to modification, by deviations from the normal standard in the state of the fluids and in the order and force and equability of action of the carneæ columnæ, and other contractile parts governing or influencing the action of the valves, and the closure and opening again of the orifices of the ventricles; and this dependence of the heart's sounds on conditions dynamic or material, wholly excluding structural defect, is so considerable, that the second sound may for a time be very variously modified or masked by strange murmurs, or even apparently suppressed in consequence of changes in the solids, of a purely *dynamic* character, and caused by humoral defect, in consequence of hæmorrhage or from the introduction of poison into the veins. And the first cardiac sound, though never wholly wanting during the active existence of the heart, may still, under similar circumstances to those referred to, present various abnormal features; may, *ex. gr.*, be as short as the second sound, or be attended or followed by anomalous murmurs, or be otherwise strikingly modified.

13th. Other conclusions, more or less satisfactorily deducible, as the Reporter conceives, from the facts stated, are,—That the peculiar sounds occurring in pericarditis, and attributed to pericardial frictions, are not referable only to vascular turgescence or dryness, &c. of the pericardium, but to lymph effused by, and adhering to, that membrane, or other equivalent obstacle to the easy and noiseless gliding over each other of the adjacent parts of the pericardium.

14th. That the ventricles are of equal capacity during life, and that the inequality usually met with after death is an illusion, as explained long since by Hervey.

15th. That the suction-influence upon the venous circulation, attributed to inspiration by various writers, is well founded.

16th. That the action of the long muscles, and more especially those of the abdominal parietes, is attended with an intrinsic sound. The notice of this fact by the Reporter has been rendered necessary in consequence of some attempts at verification, and some criticisms on an Experiment of the London Committee for 1837–38, published in the last edition of Dr. Hope's very valuable work on the Heart.

17th. That the sounds of the heart, like the motions, are governed by the same law in all warm-blooded animals hitherto examined, and probably in all kinds whatsoever in which cardiac sound occurs, viz. that the first sound in all animals is relatively longer and obtuser, and the second shorter and sharper;—that those sounds are, as in the human heart, respectively systolic and diastolic; that their causation likewise follows the same law as those of man, the first sound being mainly muscular, and the second probably exclusively valvular;—likewise, that there is the same causation and mutual relation of the cardiac and arterial pulsations.

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An Account of Researches in Electro-Chemistry. By Professor SCHÖENBEIN, *of Basle.*

THE British Association for the Advancement of Science, at their last meeting in Birmingham, honoured me with the charge to undertake a series of experiments, with the view of extending the limits of our knowledge on the connexion which is supposed to exist between electrical and chemical phænomena. The memoir which I now take the liberty to lay before the Association contains an account of the results of my late investigations, many of which may perhaps appear as not immediately bearing upon the subject in question; but I think them, nevertheless, closely connected with it. I must, however, not omit to say, that my task is still very far from being accomplished.

It is familiarly known, that a peculiar odour, resembling that of phosphorus, is developed whenever common electricity passes from metallic or any other conducting points into atmospheric air; but I am not aware of having seen it anywhere stated, that a similar odour is disengaged during the electrolysis of water, though there can be no doubt that, besides myself, more than one philosopher has observed that phænomenon. The complete ignorance in which we still remain of the true cause of the electrical smell, and of the appearance of the latter under circumstances apparently so different from each other, cannot fail to excite scientific curiosity to a high degree, and stimulate philosophers to employ all their experimental means and mental powers to clear up the mysterious phænomenon. My own endeavours to solve the problem have been manifold, and for a long time were fruitless; at last, however, I succeeded in ascertaining some facts which promise to throw light upon the subject in question. Respecting the disengagement of the electrical odour during the electrolysation of water, as well as during the passage of common electricity from points into atmospheric air, my researches have led to the following results:—

1. The peculiar smell makes its appearance as soon as the electrolysation of water begins, and continues to be perceived for some time after water has ceased to be decomposed.

2. The phosphorus smell is produced at the positive electrode only, and under no circumstances whatsoever at the

negative one; for when the gases resulting from the electrolysis of water are received in separate vessels, the smell is perceived only in that which contains oxygen.

3. The odoriferous principle can be preserved in well-closed vessels for a great length of time, whether mixed with oxygen or with detonating gas.

4. The disengagement of the smelling substance depends—

(*a*) Upon the nature of the positive electrode.

(*b*) Upon the chemical constitution of the electrolytic fluid, and

(*c*) Upon the temperature of that fluid.

With regard to the circumstance mentioned under (*a*), my experiments have shown that it is only well-cleaned gold and platina which are capable of disengaging the odoriferous principle. The more readily oxidable metals, as well as charcoal, do not possess that property at all.

It is worthy of remark that iron, though acting (agreeably to my former experiments) like gold and platina when performing the function of the positive electrode, does not permit the disengagement of the odour.

As to the condition mentioned under (*b*), I have ascertained that the odoriferous principle is obtained from distilled or common water when mixed with chemically pure, or with common sulphuric acid, with phosphoric acid, nitric acid, potash, and a series of oxi-salts. I could not get a trace of it from aqueous solutions of chlorides, bromides, iodides, fluorides, hydrochloric acid, hydro-bromic acid, hydriodic acid, hydro-fluoric acid, sulphate of protoxide of iron. If to the fluids (above mentioned), which permit the disengagement of the peculiar smell, small quantities of nitrous acid, iron vitriol, protochloride of iron or of tin are added, not the least portion of the odoriferous principle will be given out, however actively water may be electrolysed. With regard to the aqueous solution of potash, I have observed the curious fact, that the smell is sometimes disengaged from it and sometimes not, the latter case occurring much more frequently than the former. I do not know yet the cause of that anomaly.

Concerning the influence which temperature exerts upon the development of the peculiar smell, I have found that a fluid from which the odoriferous principle is abundantly disengaged at a comparatively low temperature, does not yield a trace of it when heated near its boiling point. I must not omit to state, that dilute sulphuric acid is the fluid best fitted for producing the smelling substance, and making the experiments which this memoir refers to. It sometimes happens, however, that even

in making use of that fluid, the disengagement of the odoriferous principle is either suddenly stopped or does not take place at all. In such cases, the surface of the positive gold or platina-electrode is not pure, *i. e.* it is covered with some foreign substance; and to cause the reappearance of the peculiar smell, it is necessary to clean that electrode, which, by my experience, is best done by washing it first with pure muriatic acid, and afterwards with distilled water.

5. If some pinches of powdered charcoal, iron-, tin-, zinc-, or lead-filings, or of powdered antimony, bismuth, and arsenic, or some drops of mercury are thrown into a bottle containing the odoriferous principle (mixed with oxygen), the peculiar smell disappears almost instantaneously. Iron and charcoal seem, however, to act more rapidly than the other substances mentioned do; gold and platina, when strongly heated, also destroy the smell. Small quantities of nitrous acid and aqueous solutions of proto-chloride of iron, sulphate of protoxide of iron, and proto-chloride of tin, being put into a vessel containing our peculiar principle, do likewise instantaneously annihilate the phosphorus smell.

6. A gold, or platina plate, after having been kept only for a few moments within a vessel containing the odoriferous principle (mixed with oxygen), appears to be negatively polarized. To excite that polar state in the metals mentioned, it is a condition, *sine qua non*,

(*a*) That the surface of the plate of either metal be absolutely clean and entirely free from moisture.

(*b*) That the temperature of the metal be comparatively low. Heated gold or platina do not assume the negative polar condition. The current produced by such a polarized metal is of so short a duration, that it may be considered as instantaneous. Among the metals more readily oxidable than gold and platina, it is only silver and copper that are rendered negative by being put into an atmosphere of the odoriferous principle; but the degree of polarity acquired by these metals is exceedingly slight.

7. Gold and platina having been polarized in the manner indicated, maintain their peculiar condition for some length of time when placed in common air. I have found plates which had been exposed to the atmosphere, at least for a couple of hours, still perceptibly negative.

8. A polarized stripe of gold or platina loses, almost instantaneously, its negative condition, when plunged into an atmosphere of hydrogen. If the metal is kept in hydrogen longer than just required for destroying its negative polarity, it as-

sumes, according to my former experiments, a positive condition. It will hardly be necessary to mention, that heat also destroys the polarity in question.

9. Oxygen obtained by the electrolysis of water, and deprived of its peculiar smell by the means indicated under § 5, has altogether lost its power of rendering gold and platina negative, and is, in a voltaic point of view, as inactive as oxygen prepared in the usual way.

Phænomena of Polarization caused by common Electricity.

10. A gold or platina plate, having a perfectly clean and dry surface, assumes negative polarity when exposed to the action of a positive electrical brush issuing from a metallic or any other conducting point. The longer the brush is playing upon the surface of the metal, the higher will be the degree of polarity acquired by the gold or platina. A small platina stripe, after having been exposed to the action of a brush produced by thirty turns of my electrical machine, deviated the needle of a delicate galvanometer by 60°; sixty turns, under the same circumstances, caused a deviation of 90°. It seems that the nature of the metal which performs the function of a point of emission also exerts some influence upon the degree of polarity acquired by gold and platina. *Cæteris paribus*, a point of emission consisting of gold caused a deviation of 170°, a point of brass only one of 60°. As to the metals (more readily oxidable than gold or platina), I have only succeeded with silver and copper in polarizing them negatively by common electricity. The degree of polarity acquired by the last-mentioned metals is, however, also exceedingly slight.

11. The negative electrical brush produces exactly the same voltaic effects as the positive one does.

12. A platina plate, polarized either by the positive brush or by the negative one, loses its electro-motive power when plunged only for a few moments into an atmosphere of hydrogen. All the remarks made under § 8 also apply to the case in question.

13. If gold or platina plates are connected with the prime conductor of an electrical machine, *i. e.* made points of emission, they will not assume any polar condition, however long and lively a brush may have been issuing from them.

14. Heated or moistened gold, or platina plates, cannot be polarized by the electrical brush.

15. If the points of emission are heated or moistened, the electrical brush issuing from them has no longer any polarizing power. It was impossible to excite in gold or platina even the

slightest degree of negative polarity by holding these metals ever so long against a brush issuing from heated or wetted points.

16. The electrical brush proceeding from heated or moistened points does not produce the well-known phosphorus smell. The easiest way of depriving the brush of its smell is to cover the point of emission with a piece of moistened linen.

Now in what manner are we to account for the facts above stated, and what are the inferences to be drawn from them?

As to the smell being developed at the positive electrode during the electrolysation of water, we can hardly help drawing, from the experiments mentioned in the first section, any other conclusion than that it is due to some gaseous substance disengaged (conjointly with oxygen) from the electrolytic fluid by the decomposing power of the current. But what is the nature of that substance? Is it elementary or compound? With regard to its voltaic bearings, it exhibits the strongest analogy to chlorine and bromine; of which bodies I proved, some time ago, that they possess, to a high degree, the power of negatively polarizing gold and platina. I have also formerly shown, that these metals lose again their negative polarity acquired under the influence of chlorine and bromine, when plunged into an atmosphere of hydrogen; there is, consequently, not the least doubt that, as to its electromotive power, the odoriferous principle bears the closest resemblance to chlorine and bromine. Now, does not this great analogy between the voltaic properties of chlorine, bromine, and our smelling principle, speak in favour of the supposition, that these three substances belong to the same class of bodies, *i. e.* to those which Berzelius called 'halogenia'? If we take into further consideration the facts, (*a*) that most metals destroy the peculiar smell, that is, combine with the odoriferous principle in a direct manner, and even at a low temperature; (*b*) that the said principle is not disengaged at the positive electrode, unless the latter be composed of gold or platina; that is to say, of an eminently electro-negative metal; (*c*) that the odoriferous body is not eliminated by the current, if the electrolytic fluid happens to contain a substance having a strong affinity for oxygen, for instance, sulphate of protoxide of iron; and (*d*) that our peculiar principle is always set free at the positive electrode, and never at the negative one; I say, if we duly consider all these facts, we can hardly help drawing from them the conclusion, that the odoriferous substance is a body very like chlorine or bromine. The odoriferous principle, however, may perhaps be nothing but a secondary result of the electrolytic action. Such is no doubt

possible, and indeed it was the first view I took of the case. The following reasons, however, seem to speak against the correctness of such a supposition. As chemically pure water (or what we take as such), mixed with sulphuric, nitric, and phosphoric acids, with potash and many oxi-salts, yields the odoriferous principle, we must conclude that the latter proceeds from water, and not from the other substances. Now what secondary product does water allow to be formed at the positive electrode? The oxygen being eliminated at the latter, might certainly combine with some water, and produce peroxide of hydrogen. But this compound is not gaseous at the common temperature, and its vapour is wholly inodorous. I have besides observed, that platina enveloped with a film of peroxide of hydrogen, is positive to common platina. From these facts it follows, that the odoriferous principle cannot be peroxide of hydrogen. Or does another perhaps exist, consisting of hydrogen and oxygen, and containing more of the latter element than the peroxide does? Are perhaps even chlorine and bromine compounds of a similar description? The peroxides of manganese, lead, and silver, exhibit the same voltaic properties as chlorine and bromine, both groups of bodies being eminently electro-negative. Such a strong analogy, does it not indicate a similarity as to their chemical constitution? I do not venture to answer any of these questions. The present state of chemical science does not yet warrant us to speak of chlorine and bromine as of compounds, and I shall therefore consider the odoriferous principle as an elementary body, and call it "Ozone," on account of its strong smell.

Now if we take it for granted that ozone is an elementary substance, and knowing that it originates in water, we must conclude that this fluid is made up of two electrolytes, one consisting of hydrogen and oxygen, the other of ozone and some electro-positive body. When a current is made to pass through such a fluid, both electrolytic compounds are decomposed, their anions, oxygen and ozone, being evolved at the positive electrode, their cations at the negative one. As to these cations, we know well enough that one of them is hydrogen. But is ozone also, like oxygen, united with hydrogen? All the experiments I have hitherto made with the view of discovering in the gas evolved at the negative electrode something besides hydrogen, have led to negative results, a circumstance which seems to prove that ozone, as met with in water, is combined with hydrogen.

I do not, however, yet consider this point as definitively settled. That (what we call) pure hydrogen is capable of ren-

dering gold and platina electro-positive, seems to me so extraordinary and so important a fact with regard to the chemical theory of galvanism, that I cannot but recommend it to the full attention of philosophers. Why indeed should a piece of platina, being surrounded with a film of hydrogen, and voltaically associated with common platina, produce a current when plunged into pure water? Which is the chemical action that possibly can take place under such circumstances? According to the present state of our chemical knowledge, it is very difficult, if not impossible, to give a satisfactory answer to that question. Has perhaps all the hydrogen hitherto prepared not been chemically pure, and does it always contain a principle still more electro-positive than hydrogen itself, that is, having a greater affinity for oxygen than hydrogen has? Careful experiments alone can decide these important points.

The fact above stated, that ozone is not developed at the positive electrode, unless the latter be either of gold or of platina, is, in my opinion, very easily accounted for. These metals having, at the common temperature, very little affinity for ozone, do not combine with it, any more than they do with oxygen in the same circumstances, whilst the other metallic bodies readily unite with the odoriferous principle*.

At a high temperature, gold and platina appear to be capable of combining with ozone†; and this property seems to account for the fact, that from heated dilute sulphuric acid, for instance, the smelling substance cannot be disengaged. It is, however, possible that ozone, in the moment of its being eliminated by the current, reacts upon the heated water, combining with the hydrogen of the latter.

The fact that no ozone is set free if the electrolytic fluid happens to be mixed with some readily oxidable substance, with iron-vitriol, for instance, seems to depend upon a decomposition of water, the oxygen of the latter uniting with the protoxide of iron, and its hydrogen with ozone. The non-appearance of the latter is indeed very easily understood, if we suppose its action to be entirely analogous to that of chlorine and bromine.

Before proceeding to the discussion of other facts, I must say a few words on the polarizing influence exerted by ozone upon gold and platina. In former papers I have endeavoured to prove, experimentally, that certain voltaic conditions which some metals (placed under given circumstances) seem to assume, are not to be considered as real modifications of those metals themselves (a view still maintained by some philosophers), but

* See § 5. † Ibid.

as changes proceeding only from certain substances being in some way or other deposited upon those metallic bodies. If, for instance, platina becomes positively polarized in an atmosphere of hydrogen, and negatively in one of chlorine or bromine, that metal itself does not undergo the least change with regard to its natural voltaic properties; and it is only the film of hydrogen or chlorine that surrounds the metal, which is to be considered as the seat of the electromotive power, or as the cause of the polarity. Exactly the same remarks apply to the negative polarity which gold and platina seem to assume when put into an atmosphere of ozone. By a sort of capillary action that substance adheres to the metal, and the latter being voltaically associated with another piece of the same metal (in its natural state) and plunged into water, the latter will be acted upon by ozone just in the same manner as under similar circumstances it would be by chlorine or bromine. The film of ozone covering the platina will unite with the hydrogen of water, and produce by that action a current. This current will last until all the ozone adhering to the platina stripe unites with hydrogen, but the quantity of that principle being exceedingly small, the duration of the current cannot be long.

Having fully developed my views on the chlorine and bromine circuits in the Philosophical Magazine (August, 1839), and everything said there applying to an ozone arrangement, I have no occasion to enter into further details respecting this branch of the subject.

As to the depolarizing action which an atmosphere of hydrogen exerts upon gold and platina when negatively polarized by ozone, it perhaps may depend upon the combination of the latter with hydrogen. In order to account for the disappearance of the polar state, it is, however, not necessary to presume the taking place of such an action. As platina becomes positively polarized by hydrogen, and negatively by ozone, it is obvious that the opposite voltaic actions of these two elements must, under certain circumstances, exactly balance each other.

It is manifest that the facts considered throw a new light upon what is usually termed negative voltaic polarization. The results which I obtained some time ago on that subject are pretty generally known. They seemed to prove that the negative polar state assumed by the positive electrode in water (holding oxi-acids dissolved) is due to a film either of oxygen or of peroxide of hydrogen. To the same cause I was inclined to ascribe the negative polarity excited in that portion of acidulated water which is near to, or in contact with, a positive electrode. From the facts above stated, it now appears that, in

both cases, the negative polarity results from the presence of ozone. Indeed water charged with that principle is negative to pure water, whilst the same fluid holding oxygen dissolved is, in a voltaic point of view, inactive to pure water. Water mixed with some peroxide of hydrogen bears to common water the same voltaic relation as zinc does to copper. Without having recourse to actual electrolysation, we may indeed produce, by means of insulated ozone, all the phænomena of negative voltaic polarization, a fact which seems to prove the correctness of the explanation offered of the phænomena in question.

I also suspect that the peculiar condition of iron, or its inactive state, has something to do with ozone; but for the present I cannot enter into that subject.

It is now time to speak of the phænomena of polarization produced by the agency of the electrical brush. On comparing them with those called forth by ozone, we cannot but perceive a strong analogy between both series of phænomena. The very same metals which become negatively polarized by ozone, are brought into a similar state by the action of the electrical brush. The same conditions to be fulfilled, in order to polarize gold and platina by ozone, are likewise requisite to render these metals negative by the agency of common electricity. The negative polarity developed by ozone is destroyed by the same means by which we annihilate the negative polar state called forth by the brush. These facts are sufficient to countenance the conjecture, that the cause of the negative polarity is in both cases the same, *i. e.* that it is a film of ozone surrounding the metals. I have stated (§ 16) that the brush can easily be deprived of its peculiar smell, and that by so doing the former loses its polarizing power. This fact clearly proves that it is not the electrical brush or discharge itself that excites in the metals exposed to its action the negative polar state, but the odoriferous principle accompanying the brush. This principle affecting our olfactory nerves precisely in the same manner, and also producing the same voltaic effects as ozone does, are we not entitled to infer that the smelling matter in the electrical brush and the odoriferous principle evolved at the positive electrode, are identical bodies? It appears to me that they are, and I do not, therefore, hesitate to ascribe the familiar electrical odour to ozone.

But how does it happen that ozone makes its appearance, whilst common electricity is passing from the points of a charged conductor into the atmosphere? To account for such a remarkable fact, we certainly must suppose that there is an

electrolytic compound present in the air, as well as we suppose one to be contained in water, and that the electro-negative constituent, or the anion of that electrolyte, is our ozone. The passage of electricity from the points of charged bodies into the surrounding air being in fact nothing but the act of the restoration of a broken electrical equilibrium, or a current, it is not difficult to conceive how ozone is set free near the points of emission. Our supposed electrolyte being present in the atmosphere, requires only to be placed within the circuit of such a current in order to be electrolysed, or to have its anion, ozone, separated from its cation. If all these suppositions be correct, it follows that the electrolysis of our ozonic compound will be most vigorous where the emission of electricity is most abundant, and that consequently, at such a spot, the strongest smell of ozone will be perceived, and platina or gold acquire the highest degree of negative polarity. Now experiments prove that such is really the case.

That the peculiar odour perceived when any terrestrial object is struck by lightning has something to do with ozone, cannot be doubted. We have been hitherto profoundly ignorant of the nature of that odour, and everything said and conjectured about it by ancient and modern philosophers must, in my humble opinion, be considered as totally unfounded. We know the fact only, and nothing more. The smell produced by lightning is usually described as being either sulphureous or phosphorous. Twice in my life I had an opportunity to observe this odour, once in the church of my native place (Mezingen in Wurtemberg), many years ago, another time in my own house at Basle, only last summer. The second case being still fresh in my memory, I shall say a few words about it. The object struck by lightning was a small chapel situated on the middle of the bridge of the Rhine, and about 200 yards distant from my lodgings. Immediately after the stroke had taken place, not only my house, but also the houses of my neighbours, were filled with a bluish vapour, and a pungent smell was perceived. Six hours after the occurrence I entered into a parlour which had not been opened all the day, and I could still perceive the peculiar odour. My testimony is certainly not wanted to establish the fact, that lightning always causes the disengagement of an odoriferous principle; but I think that, on account of the great mystery which is still hanging over that phænomenon, the number of observations and statements about it cannot be too much increased. The fact related offers, besides that peculiar interest, that the smell was perceived at a comparatively great distance from the object

struck by lightning. As far as my observations go, they incline me to consider the odoriferous gaseous substance set at liberty by the agency of lightning as ozone. Lightning being the same phænomenon on a large scale as the electrical spark or brush is on a small one, and our supposed electrolytic compound penetrating the whole atmosphere, electrolysis must take place, and consequently ozone be disengaged to a considerable amount, as often as lightning crosses our atmospheric air. The assertion of some observers, that the odour is of a sulphureous kind, and the statement of others, comparing it with the smell of phosphorus, may easily be reconciled to each other; for I have remarked that ozone, when somewhat condensed, is rather pungent, whilst the same substance mixed up with a large quantity of air, possesses a phosphorus smell. It is well known that the generality of people call any pungent odour sulphureous. Hence, if it happens that the odoriferous principle set free by lightning reaches the observer in a condensed state, he will describe it as sulphureous, but like phosphorus when inhaled mixed up with a good deal of air. Hence it follows, that the nearer the observer happens to be placed to the spot where a stroke of lightning takes place, the more pungent will be the smell perceived by him. The property of platina to assume negative polarity in a medium containing free ozone, seems to offer an excellent means to ascertain the presence of that principle in the atmosphere. It appears, therefore, to be desirable to make experiments on that subject, and to place, for that purpose, platina stripes (not being insulated) in elevated regions, particularly on days when thunder-storms are taking place.

Before closing this paper, I must not omit to put a question of some importance. Does the electrolytic compound mentioned exist in our atmosphere quite independent of its aqueous vapour, or is it (the electrolyte) carried into the air by the evaporation of water? It is a matter of course, that this question can only be answered by experiments, and I have not yet found time enough to make them. Supposing the electrolyte to be carried into the atmosphere by the evaporation of water, the electrical brush should not produce any smell when passing into absolutely dry air, and the quantity of ozone disengaged would, *cæteris paribus*, be proportional to the quantity of aqueous vapour present in the atmosphere; *i. e.* would depend upon the hygrometric state of the latter. It is hardly necessary to say, that problems of the highest scientific importance would be raised, in case it should turn out that ozone can be produced in dry air. Be that, however, as it may, the ubiquity of our elec-

trolyte can hardly fail acting a most important part in the household of nature; and it is not impossible that the electrical phænomena taking place within our atmosphere, the real cause of which is still covered in darkness, are closely connected with the workings of our presumed compound.

The fact of philosophers having not yet had the slightest notion of the existence of such a body is, I presume, no argument against its existence. If we suppose the electrolyte in question to be a substance closely resembling water in its chemical and physical properties, and existing in the latter fluid as well as in the atmosphere, only in very small quantities, it is easily conceivable why its existence has not hitherto been observed. I readily allow, however, that many researches, many experiments, must still be made before we arrive at certain results, at complete certainty, regarding the subject of ozone. Convinced as I am of its great scientific importance, I shall not fail devoting all my leisure time to its close investigation, and to sifting a matter to the bottom which promises to yield so rich a harvest of results. I should feel indeed very proud, if the British Association would honour me with the charge to present them an account of my researches next year.

It would be not right if I did not expressly state, before finishing my paper, that I owe most of the results above mentioned to a pile constructed upon my friend Mr. Grove's principle, an arrangement which cannot be too highly thought of.

C. F. Schönbein.

Bâle, August 2, 1840.

Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron, and Steel. By Robert Mallet, M.R.I.A., Ass. Ins. C. E.

140. Since my former report upon this subject was submitted to the British Association, as now printed in its Transactions, additional interest and importance has been given to every branch of the inquiry, as to the durability of iron under its various circumstances and conditions, by the rapidly-increasing introduction of iron vessels to navigation in the most difficult and lengthened voyages.

Amongst the several problems of a strictly scientific character requiring solution before the use of iron ships for distant voyages, or their economic adoption, under any circumstances, can be pronounced certain, is the great question of their durability as compared with those of timber; and it is hoped that the experiments made or in progress under the auspices of this Association, and about to be detailed, will render, in part at least, a satisfactory reply thereto. But, besides the desirableness of prolonging the existence of iron ships, it is of the utmost importance to prevent the formation of rust at all upon them under water, which, once produced, affords a "nidus" for the growth of marine animals and plants by which the ship's bottom is rendered foul, and her sailing qualities are greatly interfered with. These causes of foulness are found to adhere with the utmost obstinacy to the oxidized iron. It is part of our object to endeavour to find remedies for these evils.

141. The present report contains the first set of tabulated results which I have obtained as to the amount and nature of corrosion of cast and wrought iron under several different conditions of exposure to the chemical action of air and water, whether of the ocean or of rivers, &c. And as this subject essentially consists of two distinct parts, or is to be viewed in two different lights, namely, as a chemical or purely scientific inquiry, and as a technical one, from which useful practical results are to be derived, and as some portions of it, viewed in the former light, are still under experiment, and likely to be so for some time to come, I purpose, on this occasion, to reserve the purely scientific consideration of the subject, as far as pos-

sible, for a future and final report, and confine the present to the results and their modifying conditions which have already been obtained, and are of practical value and importance to the civil engineer, the iron founder, or the iron-ship builder.

142. I proceed, then, to state the general nature of the accompanying tabulated results of experiment. The first five tables contain the data and results of the chemical or corroding action of sea and fresh water on cast and wrought iron under five several conditions of experiment, continued during a period of between a year and thirteen months.

It will be seen that these five first tables, so co-ordinate with each other as to form one connected and comparable whole, by which have been determined the relative rates of corrosion, and the absolute amount thereof, for eighty-five several sorts of cast and wrought iron, under each of the following conditions, viz.

I.	In clear sea water, at temp.	46° to 58°	Fahr.
II.	In foul sea water, ,,	46° ,, 58°	,,
III.	In clear sea water, ,,	115°	,,
IV.	In foul river water, ,,	36° ,, 61°	,,
V.	In clear river water, ,,	32° ,, 68°	,,

143. During the period in which the several sets of specimens have been immersed, the five waters acting on them have been examined as to their physical and chemical properties.

144. The water of No. 1, that of Kingstown Harbour, contains, in a cubic foot, 12661 grains of solid matter, which analysed with precaution in the usual manner, had the following constitution reduced to per cent.:

Chloride sodium	71·32
Chloride magnesium	10·79
Bromide magnesium	0·60
Sulphate lime	4·87
Sulphate magnesia	5·30
Carbonate lime	1·73
Organic matter	5·27
Loss	0·12
	100·00

I could not detect any chloride of potassium or carbonate iron, said to be occasionally present in minute quantity in sea water. The amount of organic matter is very variable. It therefore appears not to differ much in composition from the waters of the British Channel, but considerably from those of the Mediterranean and the Atlantic Ocean, as given in the best

published analyses*. Its specific gravity is = 1027·80; and 100 cubic inches of the water taken from the surface contain, in combination, 1·43 cubic inch of gas, which proves to be atmospheric air, with traces of carbonic acid, or about one volume in seventy. This water is beautifully pellucid, and free from suspended inorganic matter. Its boiling point in glass is 214·5 Fahr., barom. 29·7 inches.

145. The following table of the amount of saline contents of sea water, from various localities, may be interesting, as bearing upon our subject:—

Table of Saline Contents in 1000 parts of Sea Water.		Authorities.
Arctic Sea	28·30	Marcet.
Arctic Sea sea water	3·50	,,
North Atlantic	42·60	,,
Equator	39·20	,,
South Atlantic	41·20	,,
Mediterranean	39·40	Laurent
Sea of Marmora	42·00	Marcet.
Black Sea	21·60	,,
Baltic	6·60	,,
Dead Sea	385·00	,,
British Channel	35·50	Sweitzer.
Irish Sea	33·76	Mallet.

146. One thousand volumes of sea water are stated, on the authority of Laurent, Bouillon, and Lagrange, to contain 62 volumes of carbonic acid. I have never been able to find as much. Dr. Marcet also states that ammonia is occasionally present in it.

147. The water of No. 2, or that of the foul sea water, taken from the mouth of the great Kingstown sewer, is found full of putrid organic matter of a black and white colour, exhales an intolerable fœtor, and is permanently milky or opalescent. A cubic foot of it contains 1379·5 grains of solid matter at a minimum, and varies, up to the full saline contents of the sea water, according to the degree of dryness of the weather, and consequent greater or less admixture of fresh water. The water *in situ* constantly evolves bubbles of hydrosulphuric acid and pond-gas = (H_2 C), of which torrents may be obtained by stirring the mud at the bottom; its solid constituents are the same as those above given for the sea water of the harbour, with a very variable proportion, however, of carbonate and sulphate of lime and of chloride of calcium, derived from the fresh water which mingles with the salt. It holds, com-

* Marcet, Laurent.

bined, one volume in thirty-six, on the average, of a mixed gas, consisting of

Atmospheric air,
Carburetted hydrogen,
Hydro-sulphuric acid,
Carbonic acid,

the proportions of which vary at different times. The residue of the water very gently evaporated yields at times traces of phosphate of ammonia. Its boiling point is in glass = 213°·5 Fahr., barom. 30·2 inches. Its specific gravity is = 1·02770 at maximum found.

148. The water from No. 3, or clear sea water, at 115° Fahr., is of course, in all respects, the same as the water from Kingstown Harbour, except containing less combined air.

149. The water of No. 4, or that from the river Liffey, within the tidal limits, consists of a variable mixture of water, having the same constitution as that of Kingstown Harbour, with the water next to follow, or No. 5. It is alternately fresh and salt with the rise and fall of tide, and always foul; much organic matter is suspended in it, and some extremely divided silex. It evolves hydrosulphuric acid and common air on boiling, and contains about one volume of these in twenty of water. One cubic foot of it contains, after filtration, 581·5 grains of solid matter, which consisted of

Putrified organic matter	28·00
Chloride sodium	49·73
Chloride and bromide of magnesium . . .	6·10
Sulphate lime	11·21
Sulphate magnesia	3·00
Loss	1·96
	100·00

Traces of ammoniacal salts also are found, and of phosphoric acid or phosphates. Its specific gravity is = 1·00227, and its boiling point is in glass 212° Fahr., barom. = 30·1 inches.

150. The last water, No. 5, or that of the clear stream of the Liffey, above the tidal limits, and above the city of Dublin, contains one volume in eleven of mixed gases, which are atmospheric air and carbonic acid, generally in about the proportion—

Air	94	cubic inches.
Carbonic acid	6	„
	100	„

It is clear, free from smell, and when first taken up is tolerably well tasted, but soon becomes, in a close vessel, unfit for drinking. A cubic foot of it contains 299 grains of solid matter, consisting of

Sulphate lime	52·53
Carbonate lime	24·44
Carbonate iron	7·33
Chloride calcium	6·91
Chloride magnesium	4·22
Chloride sodium	2·27
Loss	2·30
	100·00

It gives uncertain traces of a free alkali, probably carbonate of soda, derived in all probability from the beds of albite, over which the river Liffey passes, a fact long previously noticed by my friend Dr. Apjohn. The boiling-point of this water is 214° Fahr. in glass, barom. = 30·15 inches. Its specific gravity is = 1001·39; its saline contents vary very slightly between winter and summer.

151. All the waters in which the various classes of iron experimented on have been immersed are now described; and as the methods by which these experiments have been conducted, the particular objects in view and the precautions observed have been detailed in my previous report*, it will only be further necessary to premise that—

152. The corrosive action of air and water in the above conditions upon iron presents its effects in five characteristic states of oxidation or rust, on the surface of the metal varying with the nature of the cast iron, the mode of casting, &c. &c. These are referred to in column 13 of the tables of results, the nomenclature of which it may be necessary to explain.

It is unchangeable in all the tables, and embraces the following terms, which are thus explained. 1st, *Uniform*, or when the whole surface of the iron is found covered uniformly with a coat of rust requiring to be scraped off, and leaving a smooth red surface after it; 2nd, *Uniform P.*, or uniform with plumbago, where the surface, as before, uniformly corroded on scraping is found in some places covered with plumbaginous matter†, and leaving a "piebald" surface of red and black after it; 3rd, *Local*, where the surface of the iron is found only rusted in some places, and free or nearly free from rust in others; 4th, *Local Pitted*, where the surface is found as in the last

* Report, § 68 to 84. † Report, § 20.

case, but on scraping the rust off the metal is found unequally removed to a greater or less depth beneath it, so as to leave a pitted uneven surface; 5th, *Tubercular*, where the whole of the rust which has taken place *at every* point of the specimen has been transferred to one or more particular points of its surface, and has there formed large projecting tubercles*, leaving the rest bare.

In one or other, or some combination of these forms, every sort of iron, cast and wrought, which I have noticed, corrodes when exposed to the action of air and water, by which is meant water holding air in combination, such as all water at common temperatures found in nature does.

153. The 12th column in these tables contains the amount of water, if any, absorbed by the specimen of iron. It was conceived possible, from some known facts†, that cast iron long under the pressure of water might from its porous crystalline grain absorb the fluid more or less like a sponge; if so, it was necessary to know the amount of this as influencing the weighings. Means were therefore taken to determine the point, and the tables show that in almost every case no absorption has occurred; where it has, the result is to be attributed without doubt to a minute "blow-hole," or cavity in the casting.

It is certain, however, that under a sufficient pressure, cast iron may be caused to absorb water or other fluids, and experiments are in progress to determine the conditions of this question, which is not without interest and utility. The difficulty of obtaining cast iron impermeable to fluids is well known to the makers of hydraulic presses.

154. The tables Nos. VI., VII. and VIII. reduce into a small compass the whole of the results of the preceding ones; their own headings sufficiently explain their particular objects; it is therefore only necessary here to make some general observations on a few of the more striking results arrived at so far.

155. On the average it will be seen that the metallic destruction, or corrosion of cast iron, is a maximum in the clear sea water at the high temperature of 115° Fahr. (γ), and that it is nearly as great in the foul sea water (β), while it is a minimum in the clear river water (ε).

156. The temperature is not higher in the first case than iron in works of engineering, or in iron ships is likely to be exposed to in different parts of the world, as the following data indicate:—

* Report, § 49 to 59. † Report, § 37 to 58.

A thermometer sheltered from radiation and on land does not rise, in any part of the globe, above	+ 114°·8 Fahr.
One similarly situated on the open sea, no-where rises above	+ 87°·8
Lowest observed temperature on land . .	− 58°
Temperature of the sea in any latitude or season, never rises above	+ 86°
Nor has been observed lower than . . .	− 29° *

At the mouths of tropical tidal rivers, or in lagoons, the temperature of the water, however, may reach a much higher limit.

157. I would here remark a cause of increased corrosive action, affecting castings, such as cast-iron piling, &c., at the mouths of tidal rivers, which has not, to my knowledge, struck previous observers.

It is well known that the sea water, during the flowing of the tide, from its greater density, forces itself beneath the river water like a wedge, and slowly and imperfectly mixes with it, hence two strata, one of fresh or brackish water, the other of salt water below it. Thus while engaged in a diving-bell survey of part of the bed of the river Bann, in the North of Ireland, last year, I found, during the flow of tide, the water strongly saline at the bottom of the river, and yet fresh enough to drink within three feet of the surface, the total depth of water being about 25 feet; and in the Proceedings of the Royal Society of Edinburgh (April, 1817) will be found a paper by Mr. Stevenson, C.E., in which he describes analogous phænomena as occurring at the mouth of the river Dee, at Aberdeen, in the rivers Forth and Tay, and at Loch Eil, where the Caledonian Canal joins the Western Sea. On taking water up at various depths at Fort William, he found the specific gravity

At the surface = 1008·2,
At 9 fathoms = 1025·5,
At 30 fathoms = 1027·2,

or completely fresh at top, and salt as the sea itself beneath. Now Becquerel has proved that a homogeneous metallic surface (a rod or wire for instance) exposed to the action of a fluid menstruum, will assume a state of electrical tension, provided that the fluid in which it is immersed be of different density in two strata, *i. e.* of different corrosive power. In fact, the metal and the two layers of fluid constitute a voltaic pile of one solid and two fluid elements; hence as one end of the metallic rod will be in a positive state with respect to the other, it will be corroded faster than the other. Now this

* *Annales de Chimie*, xxvii., 432.

is precisely the condition of any casting reaching through a considerable depth of water at the mouth of a tidal river. The water is salter below than above, the part of the casting immersed therein (the lower end of a cast-iron pile for instance), will therefore be in an opposite electric condition to that of the portion above, and the amount of corrosion of the positive element due to the kind of iron, and the state of the water, will be further increased or "exalted" by the negative condition of the opposite end, which will be itself in the same proportion preserved. This principle extends to very many practical cases, as to iron plates, &c., partly immersed in a solvent fluid, and partly exposed to moist air, &c.; and it suggests the importance of giving increased scantling to all castings intended to be so situated, to allow for this increased local destruction of material.

158. In section (138) of my previous report, I stated the following as important desiderata for experimental answers as touching the subject, viz.,

I. The rate of progression of corrosion in sea and fresh water, with reference to increasing depth.

II. The comparative amount of corrosion in the same water at various temperatures, within the limits of climate and season.

III. The determination of the relation between the saltness of water and its corroding effects on iron.

I am now enabled to state the law governing each of these conditions, as deduced experimentally.

159. And first, with regard to depth: if water held in solution or combination the same volume of air or oxygen (not constitutional) at every depth, then the amount of corrosive action of the menstrua on iron or any other metal standing in its relation to air and water, at any given depth, will be to the amount of corrosion of the same iron at any other depth, inversely as the depth. This supposes the water stagnant, and that fresh supplies of combined air are derived from the surface, and not from a lateral current. It also only applies to moderate depths; and it is possible that at very great depths this law might not hold true.

160. We do not know with any certainty whether deep waters, or the ocean, contain the same proportions of combined air at all depths; but within twenty-four feet I have not been able to find any difference in the volume of combined air from that at the surface in either sea or river water.

161. This determination, of course, will not apply where a constant supply of water, holding new quantities of combined air, is brought in laterally, as in a tide-way or river. In this case,

if the proportion of combined air be the same at all depths, it seems probable the corrosion will slightly *increase* with the depth; but the matter is now under experiment.

162. The second question, namely, at what temperature the corrosive action of water on iron is a maximum, has with each (sea and fresh water) two conditions, namely, when the water is combined with air, and when it is freed from it by boiling, or otherwise.

163. In the first case, namely, in water and combined air, I find corrosion proceeds fastest in fresh water at temperatures varying between 175° and 190° Fahr.

164. I find, further, that the rapidity of corrosion is in the direct ratio of the volume of combined air at any given temperature; and lastly, I have found, on slowly heating water holding air in combination from 60° Fahr. up to 212° Fahr., that the air is evolved most freely, and in greatest volume, at 190° to 195° Fahr.; hence we at once perceive that the reason why the maximum corrosion of fresh water with combined air is between 175° Fahr., and 190° Fahr., arises from this being the point at which the attraction of the water for the air is destroyed, or nearly so, and hence the latter left free to combine with the metal.

165. If fresh water be deprived of all combined air, its corrosive action on iron ceases *in toto* in a close vessel; nor does corrosion commence at a boiling temperature; but if the vessel be open and very shallow, the heat even of ebullition does not prevent the absorption of air; and oxidation, once commenced, goes on even more rapidly than at a lower temperature.

166. Information is yet wanting as to the temperature of maximum corrosion of sea water, a question of greater intricacy and importance with reference to marine boilers, and now in course of experiment.

167. As regards the third question, namely, the relation between the degree of saltness of sea water and its corrosive power for iron at common temperatures, I find that in sea water, deprived of combined air, acting on iron in an open vessel, and having therefore to originate its corrosion by air drawn from the atmosphere, the corrosive power is inversely as the density of the solution, or the amount of its saline contents.

168. And in the case of sea water holding air in combination, the corrosive power is compounded of the direct ratio of the volume of combined air, and of some function of the amount of saline contents.

169. The tendency of dissolved salts to prevent the absorption of air by water, which is such, that a saturated solution of

sea salt, deprived of air, can scarcely be made to absorb air at all; and that in dissolving most salts, expel the combined air from the water of the solution, united with the circumstance, that the voltaic conducting power of the water is greater in proportion to the amount of its saline contents, indicate that fresh water may hold so much combined air (not to speak of carbonic acid) as to act more rapidly on iron than sea water; that, on the other hand, with much less combined air, the superior conducting power of the saline solution may place its corrosive power on a level with or above that of the former; and that, by the variable combination of these two elements, within their respective limits of saturation, any assignable ratio may exist of the corrosive power of aërated fresh and sea water.

This might seem to render our enlarged experiments in the open sea nugatory; but it will be recollected, that the composition of sea water, both as to solid and gasiform contents, is very nearly constant.

The experiments from which these conclusions* have been deduced, were made on equal parallelopipeds of the cast iron, as in class No. 1. α 77, exposed during equal times, and the oxides produced washed off, filtered and weighed; hence they were all made in vessels of limited size.

The part which the combined air plays in these reactions is very remarkable; it seems to belong to the same class of phænomena as those known both in inorganic and organic chemistry, where the presence of a third body is required to commence or sustain the reactions of the three, any two of which alone are quiescent. Thus gallic acid, lignin and other analogous substances, suffer no change, either in air or in water; but add to the water a minute portion of an alkali, or alkaline earth, and the process of oxidation commences at once. Alcohol stands in the like predicament.

170. It seems probable that the air, in the case of the reaction on iron, is not decomposed directly by the iron at all, but by its protoxide, previously formed by decomposition of the water, catalytically, or due to the presence of the combined air. If so, we should expect to find hydrogen evolved from the first moment, as well as nitrogen, produced by the decomposition of the air. But water, although combined with air, absorbs about one and a half per cent. of hydrogen, while, unless the air be previously expelled, it absorbs no nitrogen; hence decomposition proceeds for some time before hydrogen is evolved; but on stopping the reaction at an early stage, and expelling the air and

* Report, § 158 to 169.

absorbed gas, traces of hydrogen can be detected: at a subsequent stage, and especially if the mass and surface of iron be great in proportion to the volume of water, hydrogen and nitrogen are both evolved, and the white, greenish or black oxides before produced, become red. When this has arrived, the presence of air is no longer essential to carry on the decomposition of the water, the sesquioxide of iron, which acts as an acid to its own base, supplying its place. At a still later stage, ammonia is very frequently formed, especially where much carbon is disengaged from the iron in the state of plumbago. These reactions closely analogize with those presented by tin when acted on by nitric acid. This metal, when pure, will scarcely, if at all, decompose water cold; yet, when it decomposes nitric acid, it decomposes water at the same moment; hydrogen is given off, and ammonia is sometimes produced during the oxidation of the tin; but this rather digresses from the practical intention of the present report.

171. The powerful corrosive action of foul sea water (evidenced in Table No. IV.) by water holding putrifying organic matter in solution and suspension, is due, in great part, to the quantity of hydrosulphuric acid $(H+S)$ disengaged from the mud at the bottom, and with which the water is impregnated. The iron, acted on by the water in presence of its combined air and carbonic acid, forms hydrated oxides $(Fe\,O+H\,O)$ and $(Fe_2\,O_3+Fe\,O+H\,O)$, and carbonate of iron $(Fe\,O+C\,O_2)$, and probably, in some cases, basic salts of some organic acids. These, continually exposed to streams of hydrosulphuric acid, are in part converted into protosulphuret of iron $(Fe\,S)$, and in part into the bisulphuret of the protosulphuret or magnetic pyrites $(6\,Fe\,S+Fe\,S_2)$, both being formed in an amorphous state, or occasionally deposited in microscopic crystals in the tissue of decaying organic substances. Both of these sulphurets are of most unstable constitution, and rapidly oxidize under the action of air and water, forming protosulphate $(Fe\,O+S\,O_3)+6\,HO$, and the disulphate of the sesquioxide $(2\,Fe_2\,O_3+S\,O_3)+6\,H\,O$, and frequently various other more basic sulphates. These, when soluble, are washed away, and rapidly expose fresh surfaces of the iron to oxidation. In every case, the water charged with these salts has become a better conductor, and a more powerful agent in maintaining corrosion.

But organic matter in a state of putrefaction is one of the most powerful deoxidizing agents known,—so much so, as to be capable even of reducing sulphate of lime in the state of gypsum; hence these sulphates of iron are in their turn reduced in part

back to sulphurets; and accordingly, in the neighbourhood of iron exposed in these conditions, organic matters are frequently found, lined, penetrated, or coated with crystals of bisulphuret of iron ($Fe S_2$), or common pyrites, while their oxygen has gone to form carbonic acid and hydrosulphuric acid, both in their turn again to react in presence of air and water upon the iron.

Hence, then, the prodigious power of degradation of castings or forgings of iron, when exposed to the foul water of the sewerage of great cities, as so often observed; hence the cause of the destructive action of "bilge-water" upon the holding down bolts of marine engines.

172. A very interesting case, verifying the occurrence of these phænomena, has recently been observed and examined by the accurate Berthier*. "On the 15th June, 1837, an ancient malleable iron anchor was taken up from the bottom of the river Seine, nearly opposite Gros Cailloux. It was found imbedded in a conglomerate of pebbles, bones and altered wood, with grains of sand and fragments of pottery, of a light gray colour, and held together by a calcareous cement, which had accreted round the metal. The anchor was two metres long, and weighed not less than 200 kilograms. It was thought to be of the fifteenth century; its form, however, agrees with those of the sixteenth; and it cannot be more ancient than A.D. 1400. The crust was easily detached by a blow. At one end was found a piece of wood in immediate contact with the iron; this had preserved its ligneous texture, so as to be easily recognisable; but it was deeply altered in its qualities. Its aspect was that of a dark gray homogeneous mass, with an uneven fracture, and it was strongly magnetic. By calcination and roasting, it lost 0·375 of its weight, and exhaled a strong odour of sulphurous acid. Acetic acid dissolved from it 0·65 of pure carbonate of lime, while hydrochloric acid dissolved it nearly entirely with disengagement of hydrosulphuric acid.

"The residue was composed of portions of unaltered wood, mixed with a small quantity of persulphuret of iron (bisulphuret).

"The analysis of the whole gave

Carbonate lime	0·65
$Fe S$ = protosulphuret iron	0·18
$Fe S_2$ = persulphuret iron	0·07
Ligneous matter	0·10
	1·00

* *Annales des Mines*, vol. xiii. p. 664.

The iron must be, for the greater part, in the state of magnetic pyrites ($6 FeS + FeS_2$), and the remainder in the state of persulphuret. The gray paste of the crust is coloured likewise by the sulphuret of iron [Berthier does not say which].

"The production of sulphuret of iron at the surface of this anchor in the Seine in contact with wood, is not surprising, since we know that its waters contain sulphate of lime, and that sulphates in solution are converted slowly into sulphurets in presence of organic matter, with production of carbonate of lime.

"The carbonic acid, dissolved in the water, must have had likewise some influence on the results of this reduction, and it is probably to its presence that we may attribute the formation of the persulphuret of iron."

These facts sufficiently indicate the accordance to nature of the theory of reaction of putrid waters which has been advanced, and are fertile in conclusions of practical importance to the engineer occupied in works of construction in iron, connected with the docks or harbours of large towns, or in similar situations.

173. The average minimum corrosion is indicated (by Tables V. and VI.) as occurring in clear river water, containing air in combination. This difference below the index of corrosion for clear sea water is to be accounted for upon the general principles already laid down *; and as subsidiary causes influencing the results are to be noticed, the absence of all extraneous corrosive agents, and the circumstance that the coat of oxide of iron formed in fresh water adheres obstinately to the iron, often forming imperfect crystals, of brown hematite (*fer oligiste*), and is not removed in a loose pulverulent form with the same ease as it is in sea water, and hence acts in some degree as a cloak, or partially impervious covering, to defend portions of the metal from further action.

174. It will be further observed, from Tables III. and VI., that wrought iron suffers greater loss by corrosion in hot sea water (temp. 115° Fahr.) than under any other circumstances—an important result as respects the construction of marine engines and boilers. Upon the latter point a special set of experiments are in progress, having in view principally the points of inquiry suggested †; and should the results of these experiments give a decidedly advantageous point of concentration at which to work marine boilers (other circumstances being considered), there will be no difficulty, by the aid of the brine-pumps now occasionally used in first class steamers, and of Mr. Sea-

* §§ 167, 168, 169.

† First Report, § 78.

ward's salt gauge, in preserving any such saline condition in the water within the boilers as may be desirable.

175. These Tables also show that in general the removal of the exterior "skin" of a casting by planing or filing, to the depth of one fourth of an inch or more, greatly increases the corrosive action of air and water upon it, so that the cast irons so circumstanced show an average amount of corrosion, or, as I have ventured to name it in the Tables, have an *index of corrosion* not much less than that of wrought iron. This shows prominently the value of a close-grained and dense metallic surface for durability.

176. We further remark, that while wrought iron corrodes faster than cast iron, with the skin so removed, in clear sea water, on the contrary, the cast iron, with its surface or skin removed, corrodes faster than wrought iron in clear river water. This is due to the circumstance that the coat of hardened oxide (*fer oligiste* *) formed in clear river water, adheres much less obstinately to cast than to wrought iron, and hence mechanically protects the former less, while in sea water the coat of oxide formed is more or less pulverulent in both cases.

177. There are two facts of an altogether novel and singular character which these Tables present us with for the first time —the first, that "chilled" cast iron, of whatever sort, upon the whole corrodes faster than the same sort of iron cast in green sand; the second, that the size, or scantling (and perhaps the form) of a casting in iron forms one element in the rate of its corrosion in water.

178. With respect to the first, I have remarked †, that chilled cast iron is that which, as compared with mottled or dark gray cast irons, should corrode with the least rapidity on principles considered as established. The facts now for the first time elicited by experiment, however, show the direct contrary to be the case. This may appear at first sight to conflict with the principles already laid down; it does not, however, do so in any respect. It is still quite true that chilled cast iron (that is to say, cast iron containing a minimum of suspended or uncombined carbon, and of the highest density) will corrode the most slowly, *provided it be homogeneous* ‡. But practically, the exterior surface of no chilled casting *is* homogeneous; on the contrary, it is variable to a greater degree than that of any other sort of casting, hence the formation of those innumerable voltaic couples by whose action corrosion is promoted: in other words, the results of the present

* § 173. † See §§ 39, 44, 49. ‡ § 55.

experiments show that the voltaic action produced at the surface of chilled cast iron, by its want of homogeneity, *increases* the corrosion of the metal by menstrua, to a *greater* extent than its great density and hardness, and small amount of uncombined carbon, are *capable of retarding* its corrosion, in comparison with other sorts of cast iron. In confirmation of this it will be observed, that in almost every case the condition of the corroded surface of the "chilled" specimens has been "tubercular,"—a form of rust which, whenever it is found on iron, is an unfailing index of a want of uniformity of substance. This want of homogeneity, however, is less in every chilled casting as we recede from its surface towards the interior; and, accordingly, I expect that the result of the next two years' corrosion of those specimens, the whole of which are now immersed, and proposed to remain so for that period, will show rather a diminished excess in the index of corrosion of "chilled" over the other sorts of cast iron; the difference also diminishes with increase in bulk of a chilled casting, which must be more uniform the larger it is.

179. This leads to the second fact brought to light by these results, viz. that the size (and perhaps the form) of castings in iron influences their rate of corrosion. With the view to determine whether any difference in this respect might exist, it will be seen that in the series α, immersed in clear sea water, nearly every sort of cast iron has duplicate specimens experimented on; viz. of one inch in thickness by five inches square, and of one quarter of an inch in thickness by five inches square, but differing in no other respect whatever save in this one dimension only. Yet it will be observed, that throughout the amount of corrosion of the quarter of an inch, or thinner pieces, is greatly more than that of the thicker, or one-inch pieces of each sort of iron.

The difference is greatest in the softest and most carbonaceous, or rather "graphitic" cast irons, and least in the hard, dense, silvery cast irons. Thus in the Vartey Hill (No. 2) hot blast iron, the index of corrosion of the quarter-inch casting to that of the one-inch, is about 5·5 : 1; in the Cinderford (No. 1) cold blasts as 10·35; in the Muirkirk (No. 2) cold blast as 11·5 : 3, while in the Calder (No. 4) hot blast it is only as 6·76 : 6·20, or nearly in ratio of equality.

This very striking circumstance would scarcely have been predicted before the present results forced it on our notice; yet its rationale is easy upon principles just applied to the case of "chilled" castings. These thinner castings have cooled much faster, and more irregularly than the thicker, or one-inch

ones; hence are much less homogeneous, and contain dispersed veins and patches harder than the rest of their substance; hence again the formation of voltaic couples, and accelerated corrosion of surface.

180. This novel fact leads us to some important practical deductions. We at once see the advantage in durability that weight for weight castings of massive scantling have over those of attenuated ribs and "feathers." We see the importance of casting the "feathers" on ribbed castings intended to be submerged, of equal scantling with the other parts to which they are attached, otherwise the attenuated rib will be eaten away long before the principal parts of the casting will have suffered much; and this not merely because there is less *stuff* in the rib to *be* eaten away, but because its smaller size gave cause for its being eaten away proportionally *faster*, and in preference to the grosser rib.

181. We see the importance of having all ribbed castings *cooled in the sand* before being stripped from the moulds, so as to ensure the greatest possible uniformity of texture if intended to be submerged. Indeed, this precaution ought to form part of the engineer's specification for guidance of the founder in preparing castings for every aquatic work, and for other reasons it might be added for every work.

182. These views give the rationale of the fact which has been often noticed, but never explained, that the back ribs, of cast iron sheet piling, decay much faster than the faces of the piles, although the latter are more exposed. Thus in the Blackwall piling the front ribs of the main piles are two and a half inches thick, while the "feather" or back ribs are but one and a quarter of an inch; in the sheet piles the front ribs are one and a half or one and a quarter inch, and the feathers but one inch.

183. The principles we have now got also indicate that castings in "dry sand and loam," will probably be, *cæteris paribus*, more durable under water than those cast in "green sand."

184. In general, the results of these experiments show that the cast irons with low commercial marks, the numbers 3 and 4, &c., corrode locally and generally become pitted; while the high marks, the numbers 1 and 2, &c., corrode with considerable uniformity over their whole exposed surface, in accordance with the general principle just stated.

185. On the whole, the practical preference appears so far to be due to the Welsh cast iron for aquatic purposes; a fortunate circumstance, seeing from thence we draw the largest supplies of iron. Closeness of grain is especially desirable, and whatever can be done in way of mixture of different makes of iron

to increase this property will be valuable. Still more definite results, however, are to be expected from the examination of the suite of specimens again after their present immersion.

186. With respect to cast irons made by the hot and cold blasts, the index of corrosion appears to be, on the whole, slightly in favour of the cold blast, but not much; a circumstance possibly attributable to the hot blast iron containing a different proportion of alloyed metals of the earths and of silicon, as Dr. Thompson has shown*, and to their general difference in density, as hereafter to be noticed.

187. The great elements of difference in corrosion, however, as respects the iron itself, appear to be,—I. The degree of homogeneity of substance of the metal, and especially of its surface. II. The degree of density of the metal, and state of its crystalline arrangement. III. The amount of uncombined carbon or suspended graphite contained in the iron. The more homogeneous, the denser, harder and closer-grained, and the less graphitic, the smaller is the index of corrosion of any given specimen of cast iron.

188. The Table No. VIII. is one deduced from all the preceding, in which, assuming the rate of corrosion found by experiment for a period of 387 days, to continue uniform, the average loss per superficial foot of surface, for each general class of iron, and thence the depth to which any casting will be corroded in a period of one century is shown. This may be considered as a specimen table, showing one practical end proposed by these results.

189. The assumption here made, that the rate of corrosion will continue for a century uniformly as during the first year, is possibly not critically correct; the error, if any, however, is one not in excess, but in defect, for though the rate of corrosion may accelerate, it certainly is not likely to be retarded. This point the results of the continued experiments on the same specimen now in progress will, after two years more, fully determine. Meanwhile I have strong reason to conclude that, after a sufficient period has elapsed to enable submerged cast iron to become coated with a spongy covering of plumbago produced by its own destruction, then the further rate of corrosion *will* be somewhat accelerated, and that hence the results contained in this table are rather below the truth.

190. These deductions, in general, indicate that from three to four tenths of an inch in depth of cast iron, one inch thick, and about six tenths of an inch in depth of wrought iron will be destroyed in a century in clear sea water, a conclusion probably

* Report of the British Association, vol. vi.

not very far astray where no special perturbations or causes of corrosion supervene.

191. This gives a period of duration of about two hundred years to the cast iron wharf wall, lately constructed at Blackwall, London, before the castings shall have become so attenuated and fragile as to be useless.

192. Having been recently in correspondence with Col. Pasley, Royal Engineers, and Lieut. Symonds, of the same corps, regarding the state of the iron taken up from the wreck of the Royal George, with specimens of which I have been favoured by the former gentlemen, an opportunity has occurred, through information for which I am indebted to Lieut. Symonds, of controlling or testing the accuracy of these results in a very decisive way. A number of guns have been taken up from the wreck of the Edgar, which were upwards of one hundred and twenty-nine years under water. The depth to which they were corroded from their original dimensions, which were known, was found to be seven-eighths of an inch on the average. Now let us apply the results of our experiments to see what depth of corrosion they predict under the circumstances. Turning to Table No. VI., we find the average loss for hard gray iron with the skin removed (as in a bored gun) per square inch of surface in 387 days = 13·55 grains in foul sea water = 1951·2 grains per square foot, which, multiplied by 123·4, the times 387 days is contained in 130 years, and divided by 7000 = the grains in a pound avoirdupois, give a loss by corrosion of 34·4 lb. per square foot; but the actual loss has been 32·81 lbs. per square foot, that being the weight of a square foot of cast iron seven eighths of an inch thick. This strikingly close result is corroborated by others on iron from the Royal George, immersed for fifty-eight years, corroded from half an inch to three fourths of an inch in depth on the average, and together prove that the results of these experiments may be relied on practically.

193. I have now to make a few remarks upon the supplementary tables which accompany the five first tables of experiments, viz. those containing the results of corrosion of cast iron covered with various paints and varnishes. These were mostly such as are generally in use for such purposes, and were laid on with great care, so as to cover the whole surface completely, and leave as few microscopic pores as possible in the covering. The general results are these: of the ten sorts of paints or varnishes tried, there is not one that will completely prevent corrosion, nor one that will remain perfectly adherent or undecomposed for a single year under water. In foul water, fresh or

salt, white-lead paint perishes at once, the white-lead being probably converted into sulphuret by the action of the nascent hydro-sulphuric acid; yet white lead forms the great staple base for all the paints generally used for exposed iron works. Caoutchouc varnish appears to be the best covering in hot water, and generally in all the others asphaltum varnish. But boiled coal tar laid on, the iron being hot, has decided advantages over every other, the reasons of which we shall presently see. It is sufficiently obvious, however, that nothing very important in the way of protection is to be hoped for from any one of the coverings tried, at least when used alone.

194. Since these experiments were commenced, my attention has been drawn to the results of an analogous series obtained by Mr. James Princep of Calcutta, and contained in the Journal of the Asiatic Society of Bengal, which appear worthy of notice. The proposed extensive employment of iron steam-boats on the Ganges, and the rapid corrosion to which iron is subject in a hot climate, induced the local government to cause these experiments to be made, to endeavour to procure a varnish that should preserve the surface of the metal. Mr. Prinsep took two sets of six wrought iron plates, each 3 feet by 2 feet, upon which various paints and varnishes were applied. One set was just completely submerged, and the other half-immersed, one half of each plate being in the air and the other half in the water of the canal at Calcutta, near the Chitpur lock-gates, where it is only slightly salt. After three months' exposure the two sets were taken up and examined, and the following table contains the results, which it is to be regretted have not the numerical precision that would have been obtained by weighing the plates before and after immersion.

Experiments

Experiments on Paints and Varnishes upon Iron, made in the Ganges.

No.	Sort of covering, and how applied.	Result in 3 months, on plates wholly submersed.	Result in 3 months, on plates half in air and half in water.
1.	Coal tar, laid on hot; plate heated.	Perfectly preserved, and free from rust.	A few dots of rust at the level of the water.
2.	Thetsee varnish of Ava: two months to dry, first in cool room, and then in a stove, one coat.	Perfectly uninjured in appearance.	A line of rust at the level of the water.
3.	Dhuna, a native varnish; applied to the iron hot, in a thick uneven coat.	White and pulverulent; soft and easily rubbed off while wet; rust here and there.	Large cracks from the contraction of the part exposed to the sun; whitened where thick; black where thin; plate preserved above water.
4.	Best white-lead paint; 3 coats; allowed to dry and harden for 3 months, nearly.	Almost wholly disappeared, and blotches of rust on the surface.	Paint uninjured above water-mark, and plate preserved; but below water entirely removed.
5.	Copal varnish; 2 coats, dried rapidly.	Whitened, pulverulent, and soft, but not much oxidated.	In air less whitened; spots of rust breaking out everywhere.
6.	Spirit varnish; several coats, warmed.	Whitened, and very rusty.	Very much corroded.
7.	White wax; melted on the surface.	No trace of wax left, and very rusty.	This plate was all under water.
8.	White wash of pure lime-water.	Flaky, peeled off, and very much corroded.	In air remains on, and acts pretty well.
9.	Zinc; an edging or guard soldered round the plate when cleaned.	The clean iron exclusively corroded and bad; the zinc also oxidated.	Much more rusty in the air than under water, where a sort of crust had formed.
10.	The iron plate untouched, and covered with the usual gray oxide, as it came from the rolls.	The natural surface was a little whitened, and pretty well preserved.	Rusty on the edges, or where it had been scraped, elsewhere little injured.

Coal-tar thus appears to stand preeminent as a covering varnish for iron. The general accordance of these experiments with those of the present report is satisfactory. The anomalous result, No. IX., with the zinc protector, Mr. Prinsep considers due to its containing lead, which was proved to exist in it. Coal-tar was finally adopted for the iron vessels navigating the waters of the Ganges.

195. In the progress of these researches I procured, by the favour of Henry English, Esq., of the Mining Journal, a specimen of "zinc-paint" now sold as a covering for iron when ground in oil; that which I received is in the form of a moderately dark, gray powder, which decomposes water rapidly; sufficiently fine to form a strong full-bodied paint, when ground with oil, which dries rapidly, though not quite free from grittiness. As I could not obtain any very definite information as to the origin or mode of preparation of this substance, and its valuable qualities were highly spoken of, I considered it worth making a quantitative analysis of. It will be unnecessary here to state the method pursued; the analysis was performed with care, and the results give the following composition as that of the zinc-paint:

Sulphuret lead	9·05
Sub-oxide and oxide of zinc	4·15
Metallic zinc	81·71
Sesquioxide iron	0·14
Silica	1·81
Carbon	1·20
Loss	1·94
	100

It would hence appear to be probably some residual matter obtained in the zinc-works. I have at present specimens of it upon iron in all the six conditions of experiment, and hope at a future period to be able to report favourably of the results. I should, *à priori*, conceive that it would make an excellent body for a sound durable paint, well suited to works in iron.

196. Another sort of paint has been for some time much recommended by the vendors, made from impure black oxide manganese ground in oil. This may possibly form a powerful "drier," but, from its harsh and dense substance, can never be a suitable "body" for a paint; nor does it seem to offer any special advantage in the former respect.

197. The defects of ordinary oil-paints seem chiefly to arise from the instability of constitution of the fat oils, turpentine or other organic substances entering into their composition.

All the fixed oils may, in fact, be viewed as organic salts or combinations of the oily acids, with a compound base generally "glycerine" (C_{12} H_{11} O_{11}), or vegetable mucilage. Most of the oil of turpentine found in commerce also contains more or less pinic and silvic acids*. Now all these acids readily quit their weakly positive organic bases, to form salts with the more powerfully basic oxides of the metals, with which they are used commonly in the formation of paints, as white lead, ochres, &c. &c.; in this combination, however, the original organic bases are left free to form new combinations, under the joint action of air and moisture, and of the metal on which they may be spread. The resultant action of all which is, that the paint, in workmen's language, gets 'killed'; that is, becomes either more or less soluble in water, or pulverulent and removable by it; and in place of preserving an oxidable metal, promotes its corrosion. Pinic and silvic acids act powerfully as such, upon many bases; the former decomposes the carbonate, acetate, and most of the organic acid salts of copper, several of the earthy acetates, and the alkaline carbonates with effervescence when fused with them. Yet it is remarkable, that upon the peroxide of copper, and several other peroxides, it has scarcely any action. The electro-negative relations of commercial turpentine, then, may be neutralized, if desirable, in composing a paint; but this is in every case attended with a diminution of its power to resist the action of water. Priestley first ascertained that volatile oils, such as turpentine, absorb oxygen or atmospheric air, and combine with them in part. In this they closely resemble the fat oils, and the result is analogous in both; they finish by conversion into resins. Hatchett's experiments, and also the saponification by potass of oil of turpentine, indicate that the volatile oils do not unite directly with metallic oxides, but receive oxygen from them, become acid resins, and thus form resinous salts. Thus, if oil of turpentine be heated with peroxide of lead, water is given off. The oil becomes dark brown, viscid, and at length solid; the result is a compound of resin and oxide of lead; common resin, as Blanchet and Sell† have shown, is oil of turpentine, with an atom of oxygen combined = C_{10} H_8 O. Hence we may conclude that oil of turpentine plays no chemical part in the constitution of paints, but in so far as it has suffered these changes; in doing so its density is increased and its volume consequently diminished, and hence every oil-paint is full of microscopic pores, however carefully laid on, as may be proved

* Unverdorben, Poggendorff's *Annalen*, vii. to xxi.

† Poggendorff's *Annalen*, xxix. 133.

by the microscope; and thus, when laid on an oxidable metal, corrosion slowly takes place through these, or, as workmen say, "it rusts under the paint."

198. In the absorption of oxygen, which takes place when an oil capable of being rendered drying, such as linseed or nut oil, is exposed to the action of the atmosphere or of oxygen gas, the volume of carbonic acid formed is by no means equivalent to that of the oxygen absorbed. Hence it is obvious that the drying of oily paints is effected by a slow but real combustion of part of the hydrogen of the oil forming water, and by the partial acidification of the vegetable mucilage. This process is greatly accelerated by the presence of various substances, but particularly carbon in a solid state. It is well known that lamp-black and oils mixed together in proper proportions absorb oxygen so fast as to produce spontaneous combustion at high temperatures, yet it is the slow combustion of the hydrogen of the oil rendered more active by presence of the carbon, to which the exaltation of temperature sufficient to produce ignition was at first due. This combustion is already in part performed in the oils rendered drying by litharge, &c., and still more in the burnt oil used for the ink of copper-plate and letter-press printers, and called by them "the varnish." In fine, in every combustible compound of carbon and hydrogen, combustion, whether slow or defectively supplied with oxygen, seizes on the hydrogen first, and lastly on the carbon, and this leads, in the case of oil paints, to a succession of changes of constitution, by which at length the original solid material of the paint alone remains in feeble combination with a little decomposing resin.

199. The direction, then, in which we are able to look for improvement in the preservative power and durability of our paints, is in choosing from amongst the known groups of organic substances, those which have greater stability than the fat or fixed oils, and which, in place of being acid or haloid, are basic or neutral. Amongst the many substances of this class which occur, few seem better fitted to form a substitute for the fat oils in paints than the heavy oily matter obtained by the distillation of resin, to which M. Fremy gave the name of 'resinein*'; it has the composition ($C_{20}\,H_{15}\,O$). Now two atoms of resin = 2 ($C_{10}\,H_8\,O$); hence this oil is a fluid resin deprived of an atom of water = ($H\,O$). It is a heavy transparent oil, destitute of taste or smell, insoluble in water and alcohol, not acted on by caustic alkalies, has a high boiling-point = 480° Fahr., and reduces litharge, when boiled

* *Annales du Pharm.* xv. 282.

with it, as the drying oils do. This substance can be obtained in any quantity cheaply; all the resins possess the property of gradually combining with water when long immersed in it, and forming a porous compound, analogous in all respects to the substance thrown down by water from a solution of resin in alcohol, or from its combination with an alkaline solution. When the latter is precipitated by an acid a true hydrate is formed, consisting of an atom of resin and eight atoms of water. Even copal, after having dried as a varnish, is gradually acted on in this way by water, and becomes pulverulent. Resinein, however, does not seem to be capable of forming a hydrate, and therefore offers decided advantages as an aquatic paint.

200. Reichenbach has lately shown* that Eupion ($C_{9\frac{1}{2}}$ H_{10}) may be obtained by distillation of rapeseed oil. Naphthaline and Paraffine are both soluble in the latter; and these, from their stability of constitution and other properties, only require a suitable solvent to form the most valuable bases for paint. Naphthaline can be obtained in large quantity, in fact it is a drug with those who distil naphtha from coal-tar; and Laurent has shown† that Paraffine may be obtained in abundance by distillation from the shale of the coal formations. In the combination of these with solid materials, the principal object to be held in view to obtain a durable paint is to choose a metallic powder or peroxide least liable to be acted on by the agents most obnoxious to paints, viz. air, water, carbonic acid, and hydrosulphuric acid, and at the same time capable of intimate combination with the organic base.

201. But in a paint, or rather varnish of Naphthaline or Paraffine, no solid inorganic substance is necessarily included. The only other component needed is a suitable vehicle to cause these substances to spread and hold them upon the metallic surface. This obtained, a varnish covering, more durable than any known, would probably be produced. This is rendered almost certain by the facts already adduced by Mr. Prinsep's and my own experiments. In these, *coal-tar laid on the iron hot* is immeasurably superior to every other covering. Now coal-tar in this state consists of naphthaline enveloped in asphaltum; when coal-tar is exposed to this temperature, naphtha and other volatile matters are driven off, and the results of an imperfect destructive distillation, in which hydrogen is lost, while naphthaline is a product, remain on the iron a bright and solid varnish. This not only gives the key to the only true method of applying bituminous matter as a varnish, but it indicates the cause of the

* *Jour. fur Pract. Chim.* i. 377. † *Annales de Chimie*, lv. 218.

entire difference in preservative power observed between coal-tar so used and Swedish tar laid on cold; had the latter been heated also until decomposition commenced and naphthaline was formed, less difference probably would have been found between them.

202. In connexion with this may properly be mentioned the method stated to be used for giving the beautiful jet black varnish coating to the Silesian or Berlin castings in iron. These beautiful specimens of art are covered externally with an excessively thin coat of a black, shining, and remarkably hard varnish, which is not acted on for a considerable time by strong sulphuric or nitric acid, or for some hours by caustic potass, and which resists oxidation of the metal beneath for a long time; but, when continually exposed to air and water, at length forms isolated patches of rust, which gradually spread. The varnish is said to be thus produced:—the article of iron is suspended from a wire and covered with a very thin coat of linseed oil, it is then hung over a smoky wood fire within about a foot of the faggots, and exposed for some time to the smoke and flame—generally about thirty minutes; it is then to be lowered to within three or four inches of the fire, now become clear, and heated more strongly for a few minutes, and immediately immersed in oil of turpentine, from which it is removed to be polished with woollen cloths. A second application is sometimes requisite to give sufficient blackness and brilliancy, which is always more readily obtained with cast than with wrought iron. It is difficult to discern the precise nature of the changes which the oil undergoes in the process: watery vapour, Eupion and carburetted hydrogen are probably given off, and some of the volatile products of the wood, in imperfect combustion, may enter into combination. A different composition is recommended in the *Dictionnaire Technologique*, vol. xxii. p. 164, for producing this black varnish, viz.—

Bitumen of India	0·5
Resin	0·5
Drying oil	1·0
Copal or Amber varnish	1·0

with enough of oil of turpentine to make it spread, laid on the iron hot and baked.

203. Amongst the mechanical coverings of iron for preventing oxidation, may here be properly noticed the fusible enamel patented by Mariott, of London, and since by others. These are very fusible glasses, having, by the addition of large quantities of oxides, about the same expansion as the cast-iron culinary vessels, to which they were chiefly proposed being applied.

They are of very limited application, and appear to present a good deal of technical difficulty.

204. These somewhat scattered facts, in the chemical history of paints and preservative varnishes, are little more than sufficient to show us the barrenness of this region of art, which has received no cultivation as yet but that of continued tentation on the part of the workman, undirected by scientific principles. Much might be hoped for, important in technical results, by the enlargement and correction of our still defective knowledge of the organic chemistry of the fixed and volatile oils, the resins and the bitumens. To paints or varnishes *alone*, however, we are not to look for the means of complete protection from corrosion for oxidable metals; their liability to removal by slight external forces precludes this; their proper place, as mechanical protectors, will be found subsidiary to those which are dependent on chemical or electrical relations; and one of their most important uses will probably be found in their application, in union with substances poisonous to animal and vegetable life, to the bottoms of iron ships, to prevent the "fouling" produced by their accumulation, and now found of so much inconvenience.

205. At the period of publication of the previous report, the preservation of cast and wrought iron, by the electro-chemical action of zinc, was beginning to excite that attention which was first drawn to it by the views of Sir Humphry Davy, and the subsequent experiments of Prof. E. Davy; but there had not been time to enable any very decided results to be given in that report. I am now, however, in a condition to state the results of a tolerably complete train of experiments made on the protective powers of zinc, to iron and steel under various circumstances, some of which have been continued for upwards of two years.

The experiments I have made on the electro-chemical power of protection of zinc to iron are divided into two great classes—those in fresh water and those in sea water; and each of these classes again divides itself into two, namely, those made with the preserved and preserving metals submerged to a greater or less depth in the fluid, and those in which the metals were exposed freely to air, and covered by an indefinitely *thin film* of water constantly renewed, or, in technical language, to "wet and dry. In each of these conditions experiments have been made on the protected metal, in presence of zinc in a massive form *in simple contact*, through the intervention of the solvent or fluid in which both were immersed, and also when the protected metal has had voltaic contact established with the zinc by

actual union, or, as I shall call it, *in metallic contact*, as in the case of zinked iron, or iron coated with zinc at its fusing temperature. Hence there have been made eight distinct trains of experiment on this one branch of the subject, each of which has been carried on upon cast iron, upon wrought iron, and upon steel, as the following scheme will serve to indicate:

All freely exposed to air and carbonic acid.

Cast iron and zinc.	In simple contact..	Submerged 12 inches	In sea water.
			In fresh water.
		Submersion indefinitely small	In sea water.
			In fresh water.
	In metallic contact.	Submersion 12 inches	In sea water.
			In fresh water.
		Submersion indefinitely small	In sea water.
			In fresh water.
Wrought iron and zinc.	In simple contact..	Submersion 12 inches	In sea water.
			In fresh water.
		Submersion indefinitely small	In sea water.
			In fresh water.
	In metallic contact.	Submersion 12 inches	In sea water.
			In fresh water.
		Submersion indefinitely small	In sea water.
			In fresh water.
Cast steel and zinc.	In simple contact..	Submersion 12 inches	In sea water.
			In fresh water.
		Submersion indefinitely small	In sea water.
			In fresh water.
	In metallic contact.	Submersion 12 inches	In sea water.
			In fresh water.
		Submersion indefinitely small	In sea water.
			In fresh water.

I will not venture to enter here upon the lengthened detail of these experiments, which will probably appear in a more suitable place, but merely state the method and principal results arrived at.

206. The fresh water used in all these experiments was that which supplies the city of Dublin at the north side; it comes from Lough Ouwell, in a limestone district, county Westmeath; it contains no solid matter when filtered, but a trace of carbonate of lime and of carbonate of iron. It holds in combination, however, one volume in eight of gases evolved on boiling, which consist of

Atmospheric air	94·1
Carbonic acid	5·9
	100·0 cubic inches.

The sea water used was invariably that from Kingstown Harbour, of which the analysis has been already given.

All the experiments were carried on with water and air at about 62° Fahr. The cast iron is that of α 77, (Table No. I.), or hard gray, mixed, Welsh and Scotch iron.

The wrought iron, No. 2, Welsh bar, and the steel (L) cast steel, of the Mersey Steel Company's make. The depth of immersion in all the submerged experiments was uniformly twelve inches, in glass vessels. The zinc used was nearly pure. The volume of water employed in each experiment was fifty cubic inches.

Of Cast Iron in simple contact with Zinc immersed in Fresh Water.

207. If cast iron be perfectly free from any initial stains of rust, and quite homogeneous in texture, it is electro-chemically preserved by the contact of an equal surface of pure zinc, for an indefinite period, during which the zinc is oxidated, the oxide of zinc is transferred to the surface of the iron, and forms mammillary concretions on it; after which the protective power of the zinc is greatly diminished, and at this stage the contact of any substance, even a neutral one,—such as glass with the iron,—is sufficient to originate oxidation upon it, which, once established, gradually extends, without the zinc having power to arrest it. The oxide of iron produced has the composition $(Fe\,O + Fe_2\,O_3) + H\,O$*.

208. If cast iron, having a polished surface, be suffered to contract any coating of rust, although the surface be afterwards perfectly polished to the eye, yet zinc, in simple contact, has lost nearly the whole of its power of protection; the zinc and iron both oxidize from the moment of immersion. If the surface be removed by the file to some depth, however, the remaining metal is preserved.

209. If wrought iron has been exposed to solvent action in contact with a powerfully electro-negative metal, as copper or mercury, for a considerable time, and its surface be then removed, even to the depth of $\frac{1}{50}$th of an inch, or more, with the file, and immersed in contact with zinc, the latter is found to have lost nearly all protective power with respect to it. Cast iron so circumstanced corrodes from the first moment, and the oxide is deposited in tubercles.

210. On the other hand, if wrought iron, a portion of whose

* The formulæ used for these oxides have respect merely to composition, and not to proportion, which varies with the duration of exposure.

surface has been in *metallic contact* with zinc, or other more powerfully electro-positive metal, while immersed in a solvent, have its surface removed by the file to the depth of $\frac{1}{50}$th of an inch or more, and be then immersed alone in fresh or sea water, oxidation does not take place at all for a considerable time, and only forms at length in minute detached tubercles.

211. Thus it appears that wrought iron, which has been for a length of time in contact with an electro-negative metal in presence of a solvent, acquires an electro-positive polarity, while that which has been so circumstanced with an electro-positive metal, acquires an electro-negative polarity. The same phænomena do not present themselves with cast iron to the same extent, but yet are discernible.

To this curious subject of electro-polarization, Dr. Andrews's experiments on bismuth and platina supply analogous instances; and an interesting paper on the same, as effecting copper and platina, has been much overlooked in the thirteenth volume of the Journal of the Royal Institution, p. 200. I introduce these two last experiments (209. 210) here for the purpose of remarking, that no piece of iron which has before been used for any such experiments as the present, should be used again for a different one. Before becoming aware of this, I was tormented with anomalous results.

212. I stated in my previous report, that the views of Payen and Dumas, viz. that the cause of tubercular corrosion was a slightly alkaline reaction of the corroding water, seemed to me unnecessary to account for the phænomena. I am now enabled to state, that the sole essential circumstance to tubercular corrosion is want of homogeneity in the metal corroded, and that I have obtained the most marked tubercular corrosion of cast iron in pure distilled water, and in acidulous fluids. The corroding agent must, of course, be such as will not dissolve the oxide produced; and it must be admitted, that all other things being the same, the presence of an alkali greatly exalts the tendency to tubercular deposition of oxide, which may, however, take place without it.

Of Cast Iron in simple contact with Zinc immersed in Sea Water.

213. Cast iron, perfectly free from initial rust, is perfectly preserved from oxidation in sea water by an equal surface of zinc. The latter is oxidated; but the oxide formed is not transferred to the surface of the iron, nor does it adhere to that of the zinc: it is washed away in a flocculent form, and is partly dissolved by the saline contents of the sea water.

Yet, after the lapse of a considerable time, the whole surface of the zinc becomes covered with a thin, black, hard crust of sub-oxide, on which are deposited minute crystals of calc spar, produced by decomposition of the salts of lime in the sea water. When this has taken place, the protective powers of the zinc are greatly diminished, or nearly destroyed.

Of Cast Iron in simple contact with Zinc at an indefinitely small depth in Fresh Water.

214. Cast iron, free from initial rust, so exposed in contact with an equal surface of zinc, is oxidized from the first moment of exposure. The zinc is oxidized also, and the oxide forms concretions at the point of contact of the metals, and *increases* the oxidation of both metals; so that of two equal surfaces of cast iron, exposed during equal times to an indefinitely small depth of fresh water, the one alone, and the other in simple contact with an equal surface of zinc, the latter will lose the greater amount by oxidation.

215. When cast iron, free from initial rust, is exposed *to an indefinitely small depth of sea water*, in simple contact with an equal surface of zinc, its oxidation is retarded, but not prevented, and after a time takes place, as in the last case.

Of Wrought Iron in simple contact with Zinc immersed in Fresh Water.

216. Wrought iron, free from initial rust, exposed in contact with an equal surface of zinc, is preserved from oxidation until a large amount of oxide of zinc has concreted at the point of junction of the metals, when the iron gradually begins to form tubercular points of oxide on its upper side. The oxide has the composition $(Fe\,O + Fe_2\,O_3) + H\,O$. Carbon is deposited in microscopic crystals on the zinc.

217. Wrought iron, under the same circumstances as above, but immersed in sea water, is preserved for a time. But although the oxide of zinc deposits on the iron with greater difficulty in sea than in fresh water, yet it does so at length, along with crystals of calc spar; after which the protection of the zinc becomes uncertain, and is disturbed by the contact of any neutral solid.

Of Wrought Iron exposed in simple contact with Zinc at an indefinitely small depth in Fresh Water.

218. When wrought iron, free from initial rust, is exposed thus, in simple contact with an equal surface of zinc, oxidation commences at once, and proceeds rapidly. The zinc is oxidized also, and the oxide of zinc adheres to the points of contact of

the metals in mammillary concretions. The oxide of iron formed has the composition $(Fe\,O + Fe_2\,O_3) + (Fe\,O + C\,O_2) + H\,O$.

219. When *wrought iron* is exposed under the same circumstances as above, but to *sea water*, the same phænomena as in the last case present themselves, but much more slowly, much of the oxide of zinc being dissolved in the sea water.

Of Cast Steel exposed in simple contact with Zinc, immersed in Fresh Water.

220. When cast steel, free from initial rust, is exposed in simple contact with an equal surface of zinc, the general surface of the metal remains bright, but tubercular oxidation gradually takes place at the points of junction of the steel and zinc; the latter oxidizes less as this proceeds, and finally ceases to protect the steel at all. Carbon is transferred from the steel to the surface of the zinc. The oxide formed has the composition $(Fe\,O + F_2\,O_3) + H\,O$.

Of Cast Steel in simple contact with Zinc immersed in Sea Water.

221. In this case, the same phænomena take place as in the last, but much more slowly.

Of Cast Steel in simple contact with Zinc, exposed in an indefinitely small depth of Fresh Water.

222. Cast steel, free from initial rust, thus exposed in simple contact with an equal surface of zinc, soon begins to rust in irregular patches. The zinc also oxidizes, and the oxide forms concretions at the points of contact; after which the steel oxidizes still faster, so that in equal time it loses rather more by oxidation than an equal surface of cast steel, exposed as above, alone.

223. When cast steel, free from initial rust, is exposed in simple contact with an equal surface of zinc to an *indefinitely small depth of sea water*, the same phænomena, as in the last case, present themselves, but much more slowly.

Of Wrought Iron in metallic contact with Zinc, or Zinked Iron.—Of Zinked Iron immersed in Sea Water.

224. A plate of zinked iron was immersed for twenty-five months in sea water; its whole surface was zinked. On examination, the surface was covered with a hard black coat of sub-oxide, over which was a thin coating of crystalline carbonate of lime, but no symptoms of oxide of iron were to be

seen. Very little of the zinc was dissolved, and a little loose oxides were in the bottom of the glass jar, which proved to be $(ZnO + CO_2) + (CaO + CO_2) + (FeO + Fe_2O_3) + (ZnO + Fe_2O_3) + HO$.

225. A plate the same as the foregoing in all respects, immersed the same time in a saturated solution of common salt, on examination presented the same phænomena, but less strongly marked.

Of the ratio of Zinked surface to that of Iron necessary to protect the latter, immersed in Sea Water.

226. When equal parallelopipeds of partially zinked iron are immersed in sea water, having the following ratio of zinked surface to that of the iron, viz.

	Zinc Surface.		Iron Surface.
α	4·00	:	1
β	2·00	:	1
γ	1·00	:	1
δ	0·25	:	1
ϵ	0·124	:	1
ζ	0·065	:	1
η	0·03125	:	1
θ	0·015625	:	1
ι	0·00786	:	1

the zinc is rapidly oxidized in all, and the amount of oxide of zinc formed is in the ratio of the surface of zinc exposed; the other, or $\epsilon -$, elements being all of equal surface. The oxide of zinc formed is flocculent, and does not collect either at the iron or zinc poles, and is partly dissolved by the sea water.

The iron remains bright and free from oxide, with every proportion of zinc, down to the ratio of 0·00786 : : 1 of iron. Hence the limit of protective power of zinc in metallic contact with iron immersed in sea water is between $\frac{1}{64}$th and $\frac{1}{128}$th of the surface of the latter, at which point oxidation takes place rapidly.

Of Iron in metallic contact with Zinc immersed in Fresh Water.

227. When several equal parallelopipeds of iron are immersed in fresh water, having the following ratios of zinked surface to that of iron, viz.

	Surface of Zinc.		Surface of Iron.
κ	4·00	:	1
λ	2·00	:	1
μ	1·00	:	1
ν	0·25	:	1
o	0·125	:	1
π	0·065	:	1
ρ	0·013125	:	1
σ	0·015625	:	1
τ	0·00786	:	1

the zinc in all is corroded, and the amount of oxide formed in equal times, is proportionate to the surface of zinc; the other, or ϵ—, elements being equal. The oxide of zinc is deposited on the zinc pole in mammillary concretions. The iron remains bright and free from oxide, with every proportion of zinc, down to the ratio of 0·103125 of zinc :: 1 of iron; with this and below it, tubercular oxidation takes place on the iron surface to an extent in equal times proportional to some unascertained function of the surface of zinc.

228. Hence it is proved that at the depth of immersion of all these experiments, viz. twelve inches, the limit of protective power of zinc in metallic contact with iron in fresh water lies between $\frac{1}{16}$th and $\frac{1}{32}$nd of the surface of iron; or that it requires about four times the amount of zinc surface to put in motion the same quantity of electricity, and thus to protect wrought iron in fresh water by its aid that will effect this result in sea water. But after the lapse of a considerable period in fresh water, all the other parallelopipeds began to show signs of rust or of tarnish in the inverse order of their respective surfaces of zinc; hence time alone seems requisite in fresh water to cause the protective power of any amount of surface of zinc for iron to cease, which is confirmed by the following fact.

229. A plate of iron, whose entire surface was covered with zinc in metallic contact, was immersed for twenty-five months in fresh water. On examination, much flocculent oxide of zinc had been formed, and lay in the bottom of the glass vessel, which was in some places stained with red oxide of iron. The zinc surface was found in irregularly scattered patches, wholly removed down to the iron, which was covered with peroxide. Hence about two years appear to be the limit of preservative power of zinc to iron in fresh water, applied in fusion over its whole surface by the ordinary method. It is to be noticed, that the zinc surface was removed by solution, unequally or in patches, indicating local action *ab initio*; and it has been before

shown, that as soon as oxidation takes place at any point upon the iron surface, the protective power of the zinc is at once diminished, or rendered null.

Of Iron in metallic contact with Zinc exposed to an indefinitely small depth of Sea Water.

230. When several equal parallelopipeds of iron, having the following ratios of zinked surface to those of iron, viz.

	Surface of Zinc.		Surface of Iron.
a	4·00	:	1
b	2·00	:	1
c	1·00	:	1
d	0·25	:	1
e	0·125	:	1
f	0·065	:	1
g	0·13125	:	1
h	0·015625	:	1
i	0·00786	:	1

are exposed to an indefinitely small depth of sea water, the iron remained bright and free from oxide, down to the ratio of 0·065 of zinc to 1 of iron; but in all below this the iron suffered oxidation tubercularly. The oxide of zinc formed did not adhere to either the iron or the zinc, and was partly precipitated in a flocculent form, and partly dissolved in the sea water. Within the period of experiment the limit of protective power of zinc in metallic contact with iron, under the present condition, lies between $\frac{1}{32}$nd and $\frac{1}{64}$th of the surface of the latter.

Of Iron in metallic contact with Zinc, exposed to an indefinitely small depth of Fresh Water.

231. When several parallelopipeds of iron having the following ratios of zinked surfaces to those of iron, viz.

	Surface of Zinc.		Surface of Iron.
k	30·0	:	1
l	20·0	:	1
m	10·0	:	1
n	5·0	:	1
o	2·0	:	1
p	1·0	:	1

were exposed to an indefinitely small depth of fresh water, oxide of zinc was formed from the moment of exposure, on all, which formed hard mammillary concretions on the surface of the zinc, and also in isolated centres on that of the iron; but from the ratio of equal surfaces of zinc to iron, up to the proportion

of thirty times the surface of zinc to that of iron, complete electro-chemical protective power could not be procured even for a few hours. With equal surfaces of zinc and iron the latter became red-rusty in twelve hours, in tubercular masses, the oxide formed having the composition $(Fe\ O + Fe_2\ O_3) + H\ O$.

232. From the foregoing series of experiments on the reactions of fresh and sea water on iron and zinc, besides the immediate facts obtained, we are in a condition to make some general deductions. It has been shown that the oxidizing effect of fresh water, holding one volume in eight of air and carbonic acid, is much greater than that of sea water, holding one volume in seventy of air and carbonic acid, on cast iron, wrought iron, and steel, in voltaic contact with zinc, all other things being the same; this arises from two circumstances—the difficulty with which a saline solution absorbs air when once robbed of it, but still more from the fact, that the oxide of zinc formed plays a very different part in sea water to what it does in fresh water.

233. In sea water the oxidation of the zinc produced oxide $(Zn\ O)$, and at length a coat of suboxide, which forms a distinct dark gray layer on the zinc surface, and may be detached on bending the metal so as to obtain the suboxide in a state of complete insulation from admixed metal, but none of the first adheres to the metallic surface; the whole of the oxide of zinc formed is either washed away in a pulverulent form, or is dissolved by decomposition of the sulphates, bromides, and chlorides of the sea water, forming sulphate, bromide, and chloride of zinc, while the lime and magnesia form, with absorbed carbonic acid, insoluble carbonates; or if the iron be peroxidized, the oxide of zinc forms in part a saline double oxide with the sesquioxide of iron; but the zinc surface is preserved clean and uniform to the last, either in the metallic state or as a suboxide, except when the reaction has been very slow and the electrical current very feeble; in which case, after the lapse of a long period, crystals of calc spar form on both metals.

234. Not so, however, in fresh water; here the oxide of zinc undissolved forms local concretions of oxide on the surface of the metal already covered with a coat of suboxide. Now the precise condition constituting a suboxide, as Berzelius has well remarked, is to be decomposed, under the play of very slight affinities, into protoxide and metal, as in the analogous cases of the suboxides of copper, bismuth, arsenic, &c., at each local centre of deposition, then of protoxide of zinc, the suboxide is so decomposed in fresh water, attended with

decomposition of the water itself; hence results local action on the zinked surface, between the portions of it in the metallic state and in the state of suboxide or protoxide; and hence its removal in patches, by which the iron is soon laid bare in spots, on which, when once peroxide of iron has formed to a certain extent, the protective power of the remaining zinc is at an end; for as has been shown*, the original difference in electric condition between clean iron and clean zinc is so small, that the former ceases to be negative with reference to the latter as soon as it has been rendered more positive by the presence of its own peroxide.

235. We have seen that the conditions the most favourable possible for rapid oxidation of iron consist in its exposure to "wet and dry," or to air covered with an indefinitely thin film of water constantly renewed; thus circumstanced, zinc has no protective power over iron in fresh water; and on the whole it may be affirmed, that under all circumstances zinc has not yet been so applied to iron to rank as an electro-chemical protector towards it in the strict sense; hitherto it has not become a preventive, but merely a more or less effective *palliative* to destruction†.

236. There are some contingent circumstances in the reactions of zinc and iron, in presence of air and water, which require a brief notice. All the surfaces of a parallelopiped of iron, in contact with zinc, do not lose alike by oxidation; in these circumstances, that surface which is nearest to the source of absorbed atmospheric air, especially if it be parallel to the plane of the surface of the fluid, loses the most by oxidation in a given time.

237. All other circumstances being equal, the *upper* surface of a parallelopiped of iron loses more in a given time than either of the others. The reason of this is, that the bubbles of hydrogen escape freely from the upper surface as soon as formed, and leave it constantly exposed to the action of the air and water; but they cling to the lateral and under surfaces, and so defend them more or less from the reaction. The same result is frequently observable in a piece of iron exposed to a moist atmosphere, but from a different reason; here, *in general*, dew deposits first and most copiously on the upper surface, and

* § 207.

† It is scarcely therefore necessary to notice, in way of contravention, a paper in Poggendorff's *Annalen* for last year, vol. xlvii. p. 213, giving an account of the complete preservation of certain salt-pans by bands of zinc, which are said not to have been in contact with the saline solution. The paper in question is a curious instance of the "sophisma non causæ pro causa." A recently-boiled saturated solution of common salt has no action on iron, whether zinc be present or absent.

hence it is the more moistened, and therefore the more corroded. These modifying conditions apply, whether iron be in contact with zinc or not.

238. Water is always decomposed by iron or zinc in metallic contact as soon as oxidation of either metal has commenced, and hydrogen is at first absorbed by the water, and when this is saturated, evolved; but oxidation will not commence at all either on metal in an hermetically sealed vessel of water free from air, or on a body acting in its capacity as a peroxide. Hence, while air is constantly requisite to maintain the power of decomposing the water, it is not by the decomposition of the air alone that the iron or the zinc is oxidized, as was maintained by Dr. Marshall Hall*.

239. In my former Report †, I alluded to the effect of covering surfaces of neutral solids, as glass, &c. (beneath which the solvent fluid penetrated), in arresting corrosion. In the progress of these experiments, however, I have observed some curious modifications of this condition.

240. If a clean surface of iron immersed in water be covered with a parallel surface of plate glass, leaving a film of water between, oxidation will not take place between the glass and the iron, at least for a great length of time; it very gradually creeps inwards from the edges, forming patches of green intermediate oxide; but if in place of the plane of glass a glass lens of large curvature, and thus making very small angles with the surface of the iron, be placed upon it, oxidation will commence at the point of contact, and will spread from thence, although the iron may be in such a condition, that if no glass or other neutral solid were in contact with it at all, oxidation would just *not* take place.

241. So that, in general, whether a neutral solid prevent or promote oxidation, depends upon its position in relation to the surface of the metal. This fact seems to belong to the as yet not understood power, in promoting chemical action, which extremely small orifices or fissures seem to possess, as in the action of spongy platina, of pyrophorus, of porous bodies in the condensation and the diffusion of gases, endosmose and exosmose through capillary tubes, and so forth. It has long been observed, that in a crystallizing solution, crystals first form at acute angles and on salient points.

242. If a plane of polished iron, or other oxidable metal, be fixed, forming a very acute angle with a plate of glass, ivory, &c., and both plunged into water, oxidation commences at the angle first and spreads from it, whatever be the position of the

* First Report, § 11. † § 121.

angle with reference to the horizon. If the angle be formed by two planes of iron, the same results follow. If a cut be made on a plate of polished steel with a diamond, oxidation takes place there first. Hence, in general, a rough plate of iron or steel will be acted on by air and water sooner than a smooth or polished one; and thus we perceive, in instruments of precision, the value of a well-polished or burnished surface.

243. The well-known difference in rapidity of solution between pure zinc and that containing an alloy of another metal in small quantity, first noticed by De la Rive, induced me to make a few experiments as to whether the protective power of zinc to iron could be exalted by alloying the former with a minute quantity of another metal, higher or lower in the electro-chemical scale. The following alloys were accordingly made, and equal surfaces of cast iron submitted to the action of sea water, immersed in metallic contact with these, viz.

$$
\begin{array}{r}
50\ Zn + Hg \\
100\ Zn + Ap \\
25\ Zn + Cu \\
50\ Zn + Cu \\
100\ Zn + Cu \\
50\ Zn + Sn \\
100\ Zn + Ni \\
25\ Zn + Fe \\
100\ Zn + Na
\end{array}
$$

and also with pure zinc, and alone: on examination, it was found that the alloy, in minute quantity of every metal which is electro-negative to zinc, when in contact with cast iron, increases its corrosion in sea water, including the alloy with iron itself. While the alloy in minute quantity of a metal electro-positive to zinc increases its protective power to iron, or decreases the corrosion of iron in sea water when in contact therewith; we shall hereafter see reason to conclude these alloys not to be definite combinations, at least of their entire mass, although fused together in atomic proportion, but mixtures of definite alloys with a great excess of zinc.

244. I now proceed to notice the results contained in Tables IX. and X. These tables indicate the amount of corrosion of cast iron in sea water, when exposed in voltaic contact with various alloys of copper and zinc, and of copper and tin, or with either of those metals separately per unit of surface. The alloys in Table IX. of copper and zinc, belong to the class of those generally called *brass*, those of Table X. to those usually denominated *gun-metal*.

The primary object of these two series of experiments was to determine, in all its generality, the question as to the preservative or non-preservative power of brass or gun-metal to iron in sea water, a statement affirmative of which, it will be recollected, was made at the meeting of the British Association at Liverpool. This question has been pretty fully discussed in my previous report, and it was therein shown that neither brass nor gun-metal, as commonly so called, had any protective power (of an electro-chemical character) over iron in water, but, on the contrary, promoted its corrosion. The few experiments on which this limited conclusion was made, were tried on alloys of uncertain, or at least non-atomic constitution; it was desirable not merely to set the question of protective power finally at rest, but to establish a set of practical data for the engineer as to the actual amount of increment or decrement of corrosion of iron due to the presence of various alloys of the orders brass and gun-metal, when immersed in sea water.

245. It is obvious that this question is only a particular case of a much more general one, namely, if there be three metals, A, B and C, whereof A is electro-positive, and C electro-negative with respect to B, and capable of forming various alloys, A + C, &c.; then if B be immersed in a solvent fluid in presence of A, B shall be electro-chemically preserved, and A corroded, and *vice versâ*. If B be so immersed in presence of C, B will be dissolved or corroded, and C electro-chemically preserved, the amount of loss sustained in either case by the positive metal being determined according to Faraday's general law of volta equivalents.

But now let various alloys be formed, having atomic constitutions, as 2 A + C, A + C, A + 2 C, &c., and let B be exposed to the same solvent in presence of each. Query, what will be the electro-chemical relation of the metal B to each alloy, in respect to preservation, or amount of loss by corrosion? and what will be the nature and amount of the reactions of several such alloys upon an acid or saline solution, of a third metal, or of either of those constituting the alloys? thus,

246. When the metals, zinc and lead, and their alloys, having the compositions (4 Zn + Pb), (3 Zn + Pb), (2 Zn + Pb), (Zn + Pb), (Zn + 2 Pb), (Zn + 3 Pb), (Zn + 4 Pb), are immersed under similar circumstances in a solution of acetate of lead, it would be presumed that the decomposing power of every alloy would be in proportion to the quantity of zinc entering into its composition. The result is not so, however. The zinc and the alloys (4 Zn + Pb) and (3 Zn + Pb) at once reduce the lead of the acetate of lead to the state of metal, and as rapidly as zinc alone; after

the lapse of some days, the alloys (2 Zn + Pb), (Zn + Pb), and (Zn + 2 Pb) have reduced a few scattered crystals of lead; but the remaining alloys, (Zn + 3 Pb) and (Zn + 4 Pb), act in all respects precisely as the lead itself towards its own salts.

247. When a similar set of alloys are placed in a solution of nitrate of copper, a metal which is reduced from its salts both by zinc and lead, then the zinc and the alloys (4 Zn + Pb) and (3 Zn + Pb) reduce the nitrate to metal, and the lead does so likewise. The alloys (2 Zn + Pb), (Zn + Pb), and (Zn + 2 Pb) reduce the salt to deutoxide and metal mixed; but the alloys (Zn + 3 Pb) and (Zn + 4 Pb) reduce the nitrate to deutoxide alone, without reduction of metal. From the relations in affinity for oxygen between copper, zinc and lead, it was to be presumed, that all the alloys of the two latter metals would reduce copper; but it is remarkable that all the alloys between (2 Zn + Pb) and (Zn + 4 Pb) have less power of reduction than lead alone, while the alloys (4 Zn + Pb) and (3 Zn + Pb) have at least equal power with zinc alone.

Analogous phænomena occur when solutions of other metals, reducible by either zinc or lead, are used; and also when other metals, as the alloys of copper and zinc, or copper and tin, are employed, so that no prediction can be made, from the known affinities of the component metals towards a saline solution, what shall be the affinities towards the same solution of their atomic alloys.

248. In this class of reactions it by no means always happens, that both metals of the alloy, although both separately soluble in the electro-negative element of the saline solution experimented on, are dissolved in the ratio in which they exist in the alloy; nor is it always the most electro-positive metal of the two of which the largest amount is dissolved. The presence of each metal, and of its oxides, affects the affinities of the other of them, instances of which we have in the alloy of silver and platina, soluble in nitric acid, &c. As, however, the treatment of the general question of the action of alloys, when immersed in acid or saline menstrua on the solvent, and on each constituent metal, does not properly belong to the present subject, and a sufficient general indication of their bearing upon it has been given, I reserve the details for another occasion, and pass on to remark the practical uses to the engineer of Tables IX. and X.

249. In Table IX. it will be seen that the twelfth column gives the amount of loss per square inch of surface of cast iron, with the skin removed by turning or planing (during a period comparable with all the preceding experiments), in contact with brass, and various analogous alloys of zinc and copper, and also with copper and with zinc singly. Thus the engineer is enabled

to predict the amount of loss any piece of submerged iron-work will sustain in a given time by corrosion, when brass, &c. enters as part of the construction, as, for instance, in the rollers, chain-boxes, paddle-sluices, &c. &c. of dock-gate work.

It will be seen that cast-iron *alone*, similarly circumstanced to all the rest (No. 24), suffers a loss in sea water, as compared with an equal surface of cast iron in contact with copper, as 8·23 : 11·37; that is, the copper, as might be expected, largely promotes the corrosion of the iron; but the Table also shows, what would *not* have been expected, that the alloy having the composition (7 Cu+Zn), promotes this corrosion still more powerfully, or in the ratio of 13·21 : 8·23, so that the addition of this amount of an electro-positive metal to the copper actually produces an alloy (a new metal, in fact), with higher electro-negative powers in respect to cast iron than copper itself. The Table shows that copper, and every alloy of it, with zinc, from (Zn+10 Cu) to (17 Zn+8 Cu) inclusive, are electro-negative with respect to cast iron; but that every alloy from (18 Zn + 8 Cu) to (5 Zn + Cu) inclusive, with zinc itself, are electro-positive with respect to cast iron. Now the last but one of the electro-negative alloys is that (2 Zn + Cu), which is the usual composition of British brass of commerce, which, while it does actually by its presence increase the corrosion of iron by menstrua, thus fortunately does so in a small degree, as compared with other alloys containing more copper.

250. It will be perceived that the alloys from (17 Zn + 8 Cu) to (23 Zn + 8 Cu) form a separate interpolated series, advancing each by one eighth of an atom, and differing by only a single atom of zinc from the alloy (2 Zn + Cu) which precedes, and from that (3 Zn + Cu) which follows. This was needed, and prepared after the formation of the other alloys, in order to discover *the alloy of no action*, as it may be termed, or that which, in presence of iron and a solvent, would neither accelerate nor retard its solution; and accordingly we see it lies between (17 Zn+8 Cu) and (18 Zn+8 Cu), the former being slightly electro-negative, and the latter slightly electro-positive, with respect to cast iron.

251. It was stated in the former report, that the really important direction in which to look for protection from corrosion of iron in water was indicated by some results of Schönbein, Andrews, Payen and other experimenters, and that the problem was "*to obtain a mode of electro-chemical protection, such, that while the metal (iron) shall be preserved, the protector shall not be acted on, and whose protection shall be invariable**."

This view Professor Schönbein himself, in a paper presented to

* Report, § 136.

the Chemical Section of the British Association at Birmingham, passes summary judgment upon, by affirming that "the condition, *sine quâ non*, for efficaciously protecting readily oxidable metals against the action of free oxygen, being dissolved in fluids, is to arrange a closed voltaic circle, made up on one side of the metal to be protected, and another metallic body more readily oxidable than the former, and on the other side, of an electrolyte containing hydrogen—for instance, water." Whatever opinion may be formed as to the necessity of a closed circle, it is undoubtedly not proved that the evolution of hydrogen is the condition of protection, sine quâ non; the experiments adduced do not show it, while many others might be quoted directly showing it not to be a necessary condition. This is not, however, the place for discussing Professor Schönbein's views at length, which involve the whole *quæstio vexata* of the chemical and contact theories of galvanism.

252. I proceed, therefore, to notice the seventh column of this Table, in which is given the loss of weight sustained by the alloys of copper and zinc while in presence of cast iron and the solvent. On inspecting this column it will be apparent that the losses have not taken place in accordance with the law of volta-equivalents: there can be little doubt that they *are* strictly in accordance with that law, and that the results are irresoluble from the involvement of two or more series in column seven, arising probably from some of the alloys being simple binary compounds, and others either double binary alloys, or a mixture of a binary alloy with one or other of its components in excess.

253. It will be further observed, that whereas zinc alone in protecting cast iron suffered a loss of $= 2{\cdot}95$ grains, being nearly the equivalent, the alloy ($23\ Zn + 8\ Cu$), which as fully protected the iron from all action or corrosion, sustained a loss but of $=0{\cdot}51$ grain; in other words, the protecting metal was scarcely itself acted on at all.

This, then, makes a by no means unimportant step towards obtaining the much-wished-for electro-chemical protector before spoken of; and henceforth the engineer will have it in his power, whenever the alloy ($23\ Zn + 8\ Cu$) can be used or applied in contact with cast iron, to protect the latter as fully as by zinc itself; yet with a protector which shall suffer scarcely any loss, and whose protective energy I have reason to suppose will be, from this very cause, much more permanent and invariable than I have already proved that of pure zinc to be.

254. With respect to the alloys themselves found in this Ninth and following Table, I believe so large and complete a

collection of strictly atomic alloys of the two practically important classes of brass and gun-metal has not been made heretofore.

The principal experiments on the properties of this class of alloys published, are those of Margraff; but his were not atomic alloys, nor made in a way likely to ensure a knowledge of their constitution. I have therefore deemed it worth while to make some experiments on the properties of these alloys, and have given the results in Tables XIV. and XV.: as these nearly explain themselves, it is necessary to make but few remarks on them. The alloys of zinc and copper were all made in close vessels; the copper was fused first, the zinc in another part of the same bent wrought iron tube, coated and lined with porcelain clay and plumbago. The zinc was gradually brought in contact with the copper: the apparatus excluded air, and was continually agitated, until the alloy was poured into a mould of cast iron, in which it was cast into a long strip, which solidified instantly. About seven pounds weight of each alloy were formed at once, and the constitution of each, where any cause of doubt existed, was verified afterwards by an assay. Their composition therefore is rigidly assigned—a circumstance which it is conceived gives their properties, so far as they have been ascertained, more than usual value.

255. The modulus of cohesion given is higher considerably than those found by Sir John Rennie for copper and brass (2 Zn + Cu), or commonly assigned to zinc. I have no doubt, however, of the present being correct, and the difference arises probably from the superior purity of the metals used by me.

256. The immediate change by the addition of only one eighth of an atom of zinc to the alloy (2 Zn + Cu), from a tough yellow alloy to a white one of extreme brittleness, is very remarkable. The alloy (5 Zn + Cu), and all the alloys of copper and zinc having more constituent zinc than (17 Zn + 8 Cu) are electro-positive to cast iron, or protect it in solvents; yet when the alloy of copper is reduced to the ratio of (25 Zn + Cu), or (100 Zn + Cu), the compound becomes again electro-negative to cast iron*. These indicate, in a forcible manner, that these latter are not simple alloys, but mixtures. It may be added, that the reduction to the law of volta-equivalents of the losses in the seventh column, may enable us to discover what is the constitutional arrangement of the alloys themselves.

257. It should be remarked, before leaving the subject of these alloys of Zn + Cu, that their specific gravities, as experi-

* § 243.

mentally obtained in column five, do not follow the ratio of the amount of copper, increasing as it increases, although their general tendency is towards this; the greatest perturbations take place in the interpolated series ($17 Zn + 8 Cu$) to ($23 Zn + 8 Cu$). These specific gravities are taken on the alloys just as they were cast, and suddenly cooled in the cast-iron mould; but on submitting some of them to lamination, very variable amounts of condensation took place. Hence it is probable that sudden cooling produces an effect analogous to tempering in cold water on the alloys of copper and zinc. Dussaussoy found that as the latter became soft and malleable by tempering (*trempe*), their specific gravities were reduced in variable proportions; and it matters not whether this tempering be effected in water, or by sudden cooling in a metallic mould; the alloys now in question have therefore been submitted to this process; and as no link at present exists connecting the density of such an alloy with its specific gravity after lamination, the densities now given in Tables XIV. and XV. will be found, in most instances, not to correspond with those occasionally given in books, and which have been chiefly made on alloys submitted to compression, or cast and cooled in various ways. The densities given, however, are I believe close approximations to the truth; and all the alloys having been cast in the same way, at the same temperature, and cooled at the same rate, these specific gravities must be relatively correct.

258. Table X. contains the results of the action of sea water on cast iron, in presence of copper and tin, or their alloys. What has been said of the preceding explains the general nature of this Table also. It is therefore only necessary to remark here, that as copper and tin are each singly electro-negative with respect to iron *, they both, together with every alloy in the Table, increase or accelerate the rate of corrosion of cast iron in a solvent, though in every variable degree.

The maximum increase is produced by tin alone; which indicates that tin is more powerfully electro-negative to cast iron than copper, contrary to the opinion previously held. The increase of corrosion produced generally by alloys of copper and tin is far greater than by those of copper and zinc: hence the important practical deduction, that when submerged iron-works must be in contact with either alloy, common brass, or copper and zinc is much to be preferred to gun-metal, although contrary to general practice amongst engineers.

The losses on these alloys in column seven, as in the former case, do not apparently follow the law of volta-equivalents.

* Report, § 96.

259. The ratio of the surface of the cast-iron parallelopipeds used in these two sets of experiments to that of similar slips of the alloys, is given: both iron and alloys were filed to an exact gauge, so as to present strictly equal surfaces, in pairs, and the former made all of equal weight. The amount of loss or the "index of corrosion" of cast iron in contact with any given alloy in the Tables, will of course vary according to some unascertained function of the surface of the alloy and of the iron exposed to chemical action. The law regulating this remains to be developed; it is a subject of considerable complexity and experimental difficulty. The ratio, however, of surface of the electro-negative to that of the electro-positive metal, may vary to a considerable extent without very materially affecting the results given in the present Tables, as respects their primary object.

260. These experiments were necessarily made in a limited quantity of sea water (12 cubic inches each), and all in separate glass vessels; and as this water was soon exhausted of much of its previously combined air, the eleventh and twelfth columns in each Table give the ratio of the actual corrosion in a limited quantity of water to that which would take place in an unlimited one, or in the open sea, which is deduced from the result of (α 77) in Table I. first series, being on the same sort of cast iron as the present.

261. There are several collateral points of scientific interest this branch of our inquiry presents, which I pass, as out of the subject of inquiry. I would remark, however, that the results confirm fully what had been previously stated respecting the impossibility of protecting iron by brass in the ordinary sense of the word. They also point out the inutility, not to say the absurdity, of some inventions for the so-called prevention of oxidation, for which patents have recently been obtained; for example, more than one patent for so preserving iron by dipping it into melted copper *, or coating it with copper or brass in various other ways†.

262. It has recently been proposed to substitute zinc for lead in the operation of "cramping," or running a fluid fusible metal into the joints of iron-works to secure them together, or to

* Repertory of Arts for 1839–40.

† I observe with pleasure that M. Karsten of Berlin has recently published (*L'Institut*, No. 275, April 1839) some experiments on the electro-chemical relations of alloys of copper and zinc, &c., to solutions of their own metals. It is to be regretted that his experiments do not seem to have been made on alloys of atomic constitution; but while unknown to each other travelling (though with different objects) on neighbouring roads, it is pleasant to find that our results have so far brought us to the same resting-place.

other materials, in order, by taking advantage of its positive relation to iron, to save the latter from the increased corrosion due to the presence of lead, which is strongly negative to it.

Zinc alone, however, possesses some disadvantages as a "cramping" metal; it oxidates with great rapidity when fused in an open vessel; it contracts more than lead on solidifying, and it is too rigid to permit subsequent "caulking," so as to cause it again to fill the cavity into which it was cast. The results which have been given for the alloys of zinc with copper render it extremely probable, however, that an alloy of zinc and lead might be formed eminently suitable as a "cramping metal" in contact with iron, which, while it should possess the requisite physical properties, would be found in such a relation to iron as to retard, or at least not promote, its oxidation.

263. In my previous report* I suggested the possibility of preserving electro-chemically, to a greater or less extent, the dense and hard gray cast irons in ordinary use for engineering purposes by means of contact with the softest and most carbonaceous cast irons, such as those of Scotland and Ireland. I showed that the latter sort of cast iron is, in presence of a solvent, constantly in an electro-positive relation to the former, and that of two such specimens of cast iron, in voltaic contact, there was reason to believe that the denser iron would be preserved to a greater or less extent at the expense of the other. Experiments on this subject have now been in progress for twenty-five months.

264. When four equal-sized parallelopipeds, two of very hard dense bright gray cast iron, just capable of being planed or turned, and two of soft dark gray and highly carbonaceous cast iron, are placed, one of each pair, separately in a jar of sea water, and the other pair (viz. hard and soft) in a jar of sea water together, and in voltaic contact, the pieces having been all weighed, and the sea water preserved at a constant level, &c. &c. Then, after a period of twenty-five months had elapsed, on examination the following were found to be the results as to corrosive action:—

All the pieces were found covered with a coat of red oxide, having the composition $= \overline{(Fe_2\ O_3) + (Fe\ O + C\ O_2) + H\ O}$, and much of the same had deposited in the glass vessels.

265. The piece of hard cast iron immersed singly was found, on washing off the coat of rust, clean and pretty bright, and its surface still metallic. On weighing, and also measuring by a micrometer, it was found to have lost a coat of iron over its

* § 129.

whole surface of 0·007 of an inch in depth, a result also confirmed by the amount of rust contained in the vessel, and on the piece when reduced to peroxide.

266. The piece of soft cast iron immersed alone was found, on washing off the coat of rust, to be covered with a thin coat of soft, unctuous plumbago, capable also of being washed away by rubbing with the finger; its surface was black, and filled with glittering minute scales of graphite, but had lost its metallic lustre wholly. On removing the plumbago down to the solid iron, by rubbing with a piece of hard wood and washing, the piece was found to have lost a metallic coat over its whole surface of 0·01 of an inch in depth, estimated as before, and controlled by the amount of graphite and rust reduced to peroxide.

267. Lastly, the voltaic couple, the hard and the soft iron in contact, were examined; on washing off the rust, the hard specimen appeared bright and polished, and some minute file-marks on its surface, as sharp as when placed in the sea water. The surface of the soft piece of cast iron, on the contrary, was black, full of scales of graphite without metallic lustre, and capable of being rubbed away with the finger. The two surfaces, which were actually opposed to each other and in contact, were in both almost quite free from stain or oxidation, where air and water with difficulty gained access, from reasons before explained. On washing and cleaning perfectly the hard specimen from oxide, and the soft one from oxide and plumbago, and weighing as before, the hard cast iron was found to have lost a coat of iron over its whole *exposed* surface = 0·00263 of an inch in depth, while the piece of soft cast iron had sustained a loss over *its* whole exposed surface of 0·03 of an inch in depth, both estimated as before, by weighing and measurement, and the result controlled by estimation of the peroxide and graphite produced.

268. It is hence proved, that the softest dark gray cast iron is sufficiently electro-negative, to hard bright gray cast iron, to retard the corrosion of the latter in sea water when voltaically associated with it, to the extent of *two thirds of the total amount of corrosion* that would be experienced by the same hard gray cast iron, if exposed for the same time and under similar circumstances *alone* to sea water, and that the formation of plumbago on the softer iron or positive pole, and the collection of a coat of rust on the surface of both irons, does not prevent, although it may possibly in some degree interfere with, this effect. Hence it follows, that while the voltaic relations of soft to hard cast iron are such as will not *prevent* oxidation upon either, it

is yet in our power greatly to *retard* the corrosion of the harder iron at the expense of the softer, so that the engineer is thus given a principle of guidance in the combination of different "makes" or sorts of cast iron in the same structure, when it may be desirable partially to preserve some parts at the expense of others of less structural importance*. Instances of such cases, and of the applicability of the principle here given, will at once occur to practical men.

269. The engineer of observant habit will soon have perceived, that in exposed works in iron, equality of section or scantling, in all parts sustaining equal strain, is far from insuring equal passive power of permanent resistance, unless, in addition to a general allowance for loss of substance by corrosion, this latter element be so provided for, that it shall be equally balanced over the whole structure; or, if not, shall be compelled to confine itself to portions of the general structure, which may lose substance without injuring its stability.

The principles we have already established sufficiently guide us in the modes of effecting this; regard must not only be had to the contact of dissimilar metals†, or of the same in dissimilar fluids‡, but to the scantling of the casting and of its parts§, and to the contact of cast iron with wrought iron or steel, or of one sort of cast iron with another‖. Thus, in a suspension bridge, if the links of the chains be hammered, and the pins rolled, the latter, where equally exposed, will be eaten away long before the former. In marine steam-boilers, the rivets are hardened by hammering until cold; the plates, therefore, are corroded through round the rivets before these suffer sensibly, and in the air-pumps and condensors of engines working with sea water, or in pit work, and pumps lifting mineralized or "bad" water from mines, the cast iron perishes first round the holes through which wrought-iron bolts, &c. are inserted. And abundant other instances might be given, showing that the effects here spoken of are in practical operation to an extent that should press the means of counteracting them on the attention of the engineer.

270. I have not yet been enabled to extend this part of the inquiry to fresh water, but have reason to suppose it would not be in such case attended with equally striking results from facts before stated with respect to zinc and iron in contact in fresh water; the same forces, however, still will operate with like results, only differing in degree. It seems not improbable,

* Report, § 134. † § 244—261. ‡ § 157.
§ Sect. 179—183. ‖ § 263—268.

that the softer cast irons might be alloyed with a minute quantity of some other metal, which should produce a compound still more electro-positive with respect to hard cast iron than before. This view is supported by some facts recorded by Berthier, in the *Annales des Mines*, tom. xi. p. 512, third series. Soon after Algiers was taken by the French, some ancient shot and shells were sent to France to be recast, which had been discovered in the arsenal. They were found, however, unfit for service; the metal of which they were composed was full of minute cavities, so brittle as to be easily pulverized, white and lamellar. Analyses of the shot and shells gave the following results in 1000 parts:

	Shot.	Shells.
Arsenic	0·270	0·098
Carbon	0·010	0·015
	0·280	0·113

They contained neither sulphur, manganese, calcium, nor silicon. Specific gravity of shot = 7·650, of shells = 7·585. The cast iron alloy of which they were formed was found by Berthier *to oxidate, when exposed to air and water, with unusual rapidity*: he supposes these projectiles to have been cast in Spain, of iron made from mispikel or arseniuret of iron.

271. I now proceed to make some remarks upon the specific gravities of cast iron, wrought iron, and steel, which follow in the accompanying tabulated results. In Table XI. are collected the specific gravities of all the cast irons of the preceding experiments. These specific gravities have been taken with an unusual amount of care, and by a new method, described in the former Report*, which possesses some decided advantages in point of accuracy and convenience. They have all been taken on equal-sized cubes of the several cast irons *cut by the planing-machine* from bars of equal size, viz. one inch square, and cast in the same way, at the same temperature nearly, and cooled at the same rates; all of which precautions are essential to procuring correct results.

272. Many of my specific gravities do not agree with those given by Dr. Thompson or those of Mr. Fairbairn, contained in their respective reports†. This may arise possibly from Dr. Thompson's specific gravities having been taken from pieces of the raw pig-iron, or castings of a different size from those I used, or of various dimensions with respect to each other. In Mr. Fairbairn's case, probably from the circumstance that (as

* § 71. † In vol. vi. Report of the British Association.

I have heard) his specific gravities were taken by weighing equal bulks; cubes, in fact, cut from the mass of cast iron by the chisel and file, a method in itself not susceptible of much accuracy, but rendered much more liable to error from the liability to variable condensation of volume of the iron in the processes of chipping and filing; a rough crystalline broken surface effectually prevents an exact specific gravity being taken of cast iron by the usual method of weighing such a specimen suspended in water; and no cutting out of the specimen for weighing by any method is allowable, except by the lathe or planing-machine, which operate so quietly, that no condensation of volume is likely to take place.

273. Dr. Thompson's results give the specific gravity of hot-blast iron greater than that of cold-blast. Mr. Fairbairn's, on the contrary, give the specific gravity of cold-blast iron as the greater, and to the latter conclusion my own results tend. I have entire confidence in the correctness of the specific gravities I have given, from the method and precautions taken, and the accuracy of the instrument used in the weighings—a balance of Troughton's construction, readily sensible, when loaded, to the third decimal place.

274. A correct knowledge of the specific gravities of cast iron is important in several respects to the engineer, but most of all so from the fact, that Messrs. Fairbairn's and Hodgkinson's experiments on the strength of hot- and cold-blast iron seem to indicate that the ultimate strength of cast iron is in the ratio of some function of the specific gravity, a view more recently also confirmed by Mr. Richard Evans's experiments on the strength of anthracite pig-iron.

Now the conditions rendering the specific gravity of the *same cast iron* variable, are

I. The bulk of the casting.

II. The depth or head of metal under which it has been cast.

III. The temperature at which the iron has been "poured," or run into the mould.

IV. The rate at which the casting has cooled.

The determination of the law governing the change in each of these cases is a work of some labour and difficulty, which has been partly attempted.

275. In Table XII. the results are given of the experiments I have made on Scotch, Welsh, and Staffordshire cast irons, showing the *increase* of density produced in large castings at every two feet in depth, down to fourteen feet in depth of casting. These experiments were made on pieces cut at every two feet from a shaft or cylinder of four inches in diameter, cast

vertically, in dry sand moulds. They show a very rapid increase at first, and, below four feet in depth, a nearly uniform increment of density, approximating to a common difference of 0·13.

No previous attempts have been made, to my knowledge, to ascertain these conditions of variable specific gravity in cast iron: yet their importance is obvious; for if the ultimate strength of castings is as some function of their specific gravity, the results of experiments in relation to strength of castings of different magnitudes, or cast under different heads, are not comparable, unless these conditions of specific gravity be attended to, and involved in every calculation.

276. In Table XIII. the results are given of my experiments on the *decrease* of specific gravity of the same cast iron, due to increase of bulk or volume of casting, the circumstances of head of metal, temperature and rate of cooling being the same. The irons experimented on are Scotch, Welsh and Staffordshire. The bulk of the casting in each successive experiment is double that of the preceding one; and the results show nearly an equal decrement in specific gravity in proportion to the increase of volume of the casting.

These results sufficiently show, for instance, that although the strength of rectangular beams varies directly as their breadth, yet doubling the thickness or breadth of such a cast-iron beam will not quite double its strength, as the same iron becomes less dense in the larger casting, if so be that we admit a relation between density and ultimate cohesion, of which there seems to be but little doubt.

277. In Table XI. I have arranged all the cast irons of my experiments in classes, according to the characters of their fracture, and, for the first time, attempted to establish an uniform system of nomenclature in this respect, dividing all sorts of cast iron, by fracture, into one of six classes, either

I. Silvery,
II. Micaceous, (*miratoire* of French authors,)
III. Mottled,
IV. Bright gray,
V. Dull gray,
VI. Dark gray,

which will be found sufficient to include and describe every variety; and it is much to be wished that authors on these subjects would, in future, adopt this or some similar invariable nomenclature for the character of fracture, at present usually so ill described.

278. The nomenclature, or classification of cast iron by frac-

ture here adopted, is more also than a mere set of arbitrary visual distinctions, inasmuch as each class I have made holds a constant relation between the character of its fracture and its chemical constitution. I have also given the general working character of each such class of cast iron, by which, however, it is not to be understood, but that occasionally a *mixed cast iron* may be found, possessing all these characters in working, and yet breaking with a slightly different fracture. The working characteristics given are, however, on the whole, correct.

279. The present communication, I would hope, in some degree fulfils the desire of the British Association as to a portion of this inquiry, and will be found not devoid of use to the practical engineer. I do not purpose to enter at all in the present Report upon the chemical consideration of the changes which iron occasionally undergoes by the action of various solvents in passing into a substance analogous to plumbago, nor of the organic and other products which result from such reactions; these I hope to bring forward on a future occasion, along with the results of all the other trains of experiment in progress or contemplation, and of the second immersion of all the cast and wrought irons for a period of two years, which will expire in January 1842. The results of their first immersion are now given, and with the results of the experiments now in progress, on wrought iron and steel, together with a review of the whole subject in its *purely chemical* relations, will, I expect, complete our researches.

280. The latter experiments on wrought iron and steel have been for some months in operation; and the tables of data belonging to them, which best indicate their nature and extent, have been presented; but it is not necessary to publish them at this time, as the only results of this series actually completed as yet, are the specific gravities. These are given in Table XVI.

The maximum specific gravity is that of tilted blister steel, made by the Mersey Steel Company, which is = 7·8461. The minimum specific gravity is that of cast steel in the ingot, before tilting, which is = 7·4413; it contains microscopic vesicles. The specific gravity of the iron from which both were made, is = 7·5839.

From this Table it appears, that both in wrought iron and steel the density is increased more by hammering than by rolling, and that the densest specimens of both metals break with a fibrous or very fine crystalline fracture, while the least dense have a coarse crystalline or lamellar fracture.

281. Experiments already detailed having demonstrated the great rapidity with which iron of every sort is corroded while

kept just covered with water, or between "wet and dry," a series of new experiments have been recently arranged, containing specimens of cast and wrought iron, freely exposed to all the atmospheric influences, at Dublin. These are coordinate with all the experiments, whose first results of submersion are now given, and will connect the action of water containing air and carbonic acid on iron with that of air holding water and carbonic acid in suspension, &c.; and, as the meteorological registers of Dublin are tolerably perfect, will be hereafter comparable with any such made in another locality. The data of this set of experiments may await the publication of a third report, and be given along with the results.

282. In concluding this second report upon a subject in which I feel a lively interest, and the practical bearing of which needs no further evidence than the multitude of patents, whether good or bad, for inventions intended to preserve iron, &c., which have been obtained since the publication of the first report, and in retracing the ground already gone over, I must regret the many imperfections and omissions, which I might have been enabled to avoid, could I have devoted more time to these researches. That learned *otium*, however, so necessary to successful experimental study, is denied to those who, like myself, find every day to come preoccupied with the unavoidable duties of a laborious profession. Hence, most of these experiments have been made and recorded in hours stolen from rest, or, with greater difficulty, from business.

I have to thank many individuals for specimens of iron, &c. in various conditions, and especially my young friend Mr. Charles Scanlan, for his valuable assistance in taking great numbers of specific gravities.

TABLE

Box α. No. 1. containing Specimens of Cast and Wrought

Sunk and moored at the Second Buoy in from the Western Pier Head in three ordinarily 12 to 16 feet. Temperature of water 46° Fahr. to 58° Fahr. August 3rd, 1838. Weighed again and landed August 26th, 1839; hence 1840, at one o'clock P.M., and now immersed. Specific gravity of water

Box α. No. 1. Class No. 1.

1.	2.		3.	4.	5.
No. of Experiment and mark of Specimen.	Commercial Character of Iron.	Hot or Cold Blast.	External Character of Fracture.	How Cast.	Specific Gravity of Specimen $S=\frac{W s}{w}$.
α 1	No. 1. Doulais.	Cold	Dark gray	Green	7·192
α 2	No. 1. Doulais.	Cold	Dark gray	Green	7·183
α 3	No. 3. Doulais.	Cold	Dark gray	Green	7·159
α 4	No. 3. Doulais.	Cold	Dark gray	Green	7·149
α 5	No. 1. Doulais.	Hot	Dull gray	Green	7·164
α 6	No. 1. Blaenavon.	Cold	Dark gray	Green	7·143
α 7	No. 1. Blaenavon.	Cold	Dark gray	Green	7·133
α 8	No. 4. Doulais. Finery pig	Hot	Silvery	Green	6·378
α 9	No. 4. Doulais. Finery pig	Hot	Silvery	Green	6·369
α 10	No. 1. Pentwyn. Peculiar fracture.	Hot	Micaceous	Green	7·000
α 11	No. 1. Pentwyn. Peculiar fracture.	Hot	Micaceous	Green	6·991
α 12	No. 2. Varteg Hill	Hot	Bright gray	Green	7·074
α 13	No. 2. Varteg Hill.	Hot	Bright gray	Green	7·065

Box α. No. 1. Class No. 2.

α 14	No. 1. Arigna	Cold	Micaceous	Green	7·006
α 15	No. 1. Arigna	Cold	Micaceous	Green	7·015
α 16	No. 2. Arigna	Cold	Dull gray	Green	6·799
α 17	No. 2. Arigna	Cold	Dull gray	Green	6·809

Box α. No. 1. Class No. 3. Staffordshire,

α 18	No. 3. Apedale. Cylinder Iron...	Hot	Mottled	Green	7·106
α 19	No. 3. Apedale. Cylinder Iron...	Hot	Mottled	Green	7·116
α 20	No. 1. Parkfield.......................	Cold	Mottled	Green	7·248
α 21	No. 1. Madeley Wood.	Cold	Bright gray	Green	7·115
α 22	No. 1. Lillieshal.......................	Cold	Dull gray	Green	7·205
α 23	No. 1. Cinderford.	Cold	Bright gray	Green	7·040
α 24	No. 1. Cinderford.	Cold	Bright gray	Green	7·049
α 25	No. 1. Burchill's	Cold	Micaceous	Green	6·933

No. I.

Iron, immersed in clear Sea Water, Kingstown Harbour.

and one half fathoms water, at half tide, on a clean sandy bottom. Tide rises The length of the Box lies east and west. Sunk at one o'clock P.M., the period of immersion = 387 days. Sunk a second time January 11th, in Kingstown Harbour = 1027·80.

Welsh Cast Iron.

6. Dimensions of Specimen.	7. Weight of Specimen in Grains.	8. Weight of Specimen after 387 days' exposure.	9. Total loss by Corrosion in 387 days.	10. Loss of Weight per square inch of Surface.	11. Loss of Weight referred to Standard Bar.	12. Weight of Water absorbed.	13. Character of Corrosion.
in. in. in.							
5 × 5 × 1	43011	42720	291	4·16	·392	0·	Uniform P.
5 × 5 × ·25	11871	11384	487	8·85	·834	0·	Uniform.
5 × 5 × 1	43777	43452	325	4·64	·437	0·	Local pitted.
5 × 5 × ·25	12665	12209	456	8·29	·782	0·	Local.
5 × 4 × 1	34843	34469	374	6·45	·608	0·	Uniform.
5 × 5 × 1	43558	43200	358	5·11	·482	0·	Uniform P.
5 × 5 × ·25	12185	11759	426	7·74	·730	0·	Uniform.
5 × 5 × 1	41257	41176	81	1·16	·109	0·	Tubercular.
5 × 5 × ·25	10846	10576	270	4·90	·462	0·	Tubercular.
5 × 5 × 1	41864	41547	317	4·53	·427	0·	Uniform P.
5 × 5 × ·25	11665	11169	496	9·01	·850	0·	Uniform P.
5 × 5 × 1	43785	43638	147	2·10	·198	0·	Local.
5 × 5 × ·25	12929	12339	590	10·70	1·009	7·0	Local pitted.

Irish Cast Iron.

5 × 5 × ·25	10922	10479	443	8·05	·759	0·	Uniform P.
5 × 5 × 1	40670	40331	339	4·84	·457	0·	Uniform P.
5 × 5 × ·25	11886	11453	433	7·87	·742	0·	Uniform P.
5 × 5 × 1	42915	42695	220	3·14	·296	0·	Uniform P.

Shropshire, and Gloucestershire Irons. Cast.

5×5 ×·25	12197	11789	408	7·40	·698	0·	Tubercular.
5×5 × 1	44690	44352	338	4·83	·456	0·	Tubercular.
5×4 × 1	34814	34412	402	6·93	·654	0·	Local.
5×4 × 1	34112	33770	342	5·76	·543	0·	Local.
5×3·63× 1	31818	31530	288	5·37	·507	0·	Local.
5×5 ×·25	12454	11900	554	10·07	·941	3·	Local.
5×3·75× 1	32736	32527	209	3·62	·341	0·	Local.
5×3·5 × 1	29617	28773	844	16·23	1·531	0·	Local.

Box α. No. 1. Class No. 4.

1. No. of Experiment and mark of Specimen.	2. Commercial Character of Iron.	Hot or Cold Blast.	3. External Character of Fracture.	4. How Cast.	5. Specific Gravity of Specimen $S = \frac{W s}{w}$.
α 26	No. 1. Clyde, 35 years made	Cold	Mottled	Green	7·140
α 27	No. 1. Clyde, 35 years made	Cold	Mottled	Green	7·131
α 28	No. 3. Calder	Hot	Bright gray	Green	7·061
α 29	No. 3. Calder	Hot	Bright gray	Green	7·055
α 30	No. 4. Calder	Hot	Silvery	Green	7·527
α 31	No. 4. Calder	Hot	Silvery	Green	7·518
α 32	No. 1. Gartsherry	Hot	Bright gray	Green	7·001
α 33	No. 1. Gartsherry	Hot	Bright gray	Green	6·990
α 34	No. 2. Gartsherry	Hot	Bright gray	Green	7·115
α 35	No. 2. Gartsherry	Hot	Bright gray	Green	7·106
α 36	No. 3. Gartsherry	Hot	Bright gray	Green	7·074
α 37	No. 3. Gartsherry	Hot	Bright gray	Green	7·065
α 38	No. 2. Summerlie	Hot	Bright gray	Green	7·146
α 39	No. 2. Summerlie	Hot	Bright gray	Green	7·156
α 40	No. 3. Monkland......................	Hot	Dull gray	Green	7·115
α 41	No. 3. Monkland......................	Hot	Dull gray	Green	7·124
α 42	No. 4. Monkland......................	Hot	Mottled	Green	7·285
α 43	No. 4. Monkland...	Hot	Mottled	Green	7·294
α 44	No. 2. Muirkirk	Hot	Micaceous	Green	6·971
α 45	No. 2. Muirkirk	Hot	Micaceous	Green	6·980
α 46	No. 3. Muirkirk	Hot	Dull gray	Green	6·829
α 47	No. 3. Muirkirk	Hot	Dull gray	Green	6·838
α 48	No. 1. Shotts	Hot	Dull gray	Green	7·099
α 49	No. 1. Shotts	Hot	Dull gray	Green	7·109
α 50	No. 2. Shotts	Hot	Dull gray	Green	7·143
α 51	No. 2. Shotts	Hot	Dull gray	Green	7·152
α 52	No. 3. Shotts	Hot	Bright gray	Green	7·183
α 53	No. 3. Shotts	Hot	Bright gray	Green	7·173
α 54	No. 4. Shotts	Hot	Silvery	Green	7·158
α 55	No. 4. Shotts	Hot	Silvery	Green	7·149
α 56	No. 2. Muirkirk	Cold	Dark gray	Green	7·076
α 57	No. 2. Muirkirk	Cold	Dark gray	Green	7·067

Box α. No. 1. Class No. 5.

α 58	No. 2. Doulais. Common bar ...	...	Fibrous	Green	7·587

Box α. No. 1. Class No. 6.

α 59	No. 1. Calder	Hot	Dark gray	Green	7.027
α 6	No. 1. Calder	Hot	Mottled	Chilled	7·079

Scotch Cast Irons.

6.	7.	8.	9.	10.	11.	12.	13.
Dimensions of Specimen.	Weight of Specimen in Grains.	Weight of Specimen after 387 days' exposure.	Total loss by Corrosion in 387 days.	Loss of Weight per square inch of Surface.	Loss of Weight referred to Standard Bar.	Weight of Water absorbed.	Character of Corrosion.
in. in. in.							
5 × 5 × 1	44309	43961	348	4·97	·469	0·	Uniform P.
5 × 5 × ·25	11885	11514	371	6·74	·636	0·	Uniform P.
5 × 5 × 1	43624	43276	348	4·97	·469	0·	Local.
5 × 5 × ·25	11885	11527	358	6·51	·614	0·	Local.
5 × 5 × 1	43519	43085	434	6·20	·585	0·	Tubercular.
5 × 5 × ·25	12043	11671	372	6·76	·636	0·	Tubercular.
5 × 5 × 1	43734	43334	400	5·71	·539	0·	Uniform P.
5 × 5 × ·25	11918	11404	514	9·34	·881	0·	Uniform.
5 × 5 × 1	43890	43558	332	4·74	·447	0·	Uniform.
5 × 5 × ·25	11735	11275	460	8·36	·789	0·	Uniform.
5 × 5 × 1	42513	42172	341	4·87	·459	0·	Local.
5 × 5 × ·25	11732	11265	467	8·49	·801	0·	Local pitted.
5 × 5 × ·25	11830	11238	592	10·76	1·015	0·	Uniform.
5 × 5 × 1	43920	43700	220	3·14	·296	0·	Uniform.
5 × 5 × ·25	11789	11147	642	11·67	1·101	0·	Local.
5 × 5 × 1	42795	42574	221	3·16	·298	0·	Local.
5 × 5 × ·25	12183	11701	482	8·76	·826	0·	Tubercular.
5 × 5 × 1	44600	44269	331	4·73	·446	0·	Tubercular.
5 × 5 × ·25	11534	10916	618	11·23	1·059	0·	Uniform P.
5 × 5 × 1	43388	43184	204	2·91	·275	0·	Uniform P.
5 × 5 × ·25	11894	11343	551	10·02	·945	0·	Tubercular.
5 × 5 × 1	42786	42575	211	3·01	·284	0·	Tubercular.
5 × 5 × ·25	11892	11449	443	8·05	·759	0·	Uniform P.
5 × 5 × 1	43447	43061	386	5·51	·520	0·	Uniform P.
5 × 5 × ·25	12267	11754	515	9·36	·883	0·	Uniform P.
5 × 5 × 1	44139	43911	228	3·25	·307	0·	Uniform.
5 × 5 × 1	44155	43781	374	5·34	·504	0·	Local pitted.
5 × 5 × ·25	11857	11381	476	8·65	·816	0·	Local.
5 × 5 × 1	43691	43429	262	3·74	·353	13·0	Tubercular.
5 × 5 × ·25	11901	11380	521	9·47	·893	2·0	Tubercular.
5 × 5 × 1	43225	43026	199	2·84	·267	0·	Uniform P.
5 × 5 × ·25	11672	11025	647	11·76	1·109	0·	Uniform P.

The Standard Bar of Wrought Iron.

5 × 5 × ·875	24440	23972	468	10·636	1·000	0·	Uniformly striated.

Scotch Cast Iron. Chilled.

5 × 5 × 1	42470	42042	428	6·11	·576	0·	Uniform P.
5 × 5 × 1	43570	43034	536	7·65	·722	0·	Tubercular.

Box α. No. 1. Class No. 7.

1. No. of Experiment and mark of Specimen.	2. Commercial Character of Iron.	Hot or Cold Blast.	3. External Character of Fracture.	4. How Cast.	5. Specific Gravity of Specimen $S = \frac{W s}{w}$.
α 61	No. 2. Pentwyn.	Hot	Mottled	Green	7·017
α 62	No. 2. Pentwyn.	Hot	Silvery	Chilled	7·129

Box α. No. 1. Class No. 8.

α 63	No. 2. Apedale.	Cold	Mottled	Green	7·268
α 64	No. 2. Apedale.	Cold	Silvery	Chilled	7·603

Box α. No. 1. Class No. 9.

α 65	No. 3. Arigna	Cold	Dull gray	Green	7·141
α 66	No. 3. Arigna	Cold	Mottled	Chilled	7·308

Box α. No. 1. Class No. 10.

α 67	Hardest procurable. Old fire-bars	....	Silv. Crystals.	Chilled	7·624
α 68	½ No. 1. Calder + ½ No. 2. Pentwyn	Hot Hot	Close dull gray	Green	6·978
α 69	½ No. 2. Arigna + ½ No. 2. Pentwyn	Cold Hot	Close dull gray	Green	7·050

Box α. No. 1. Class No. 11. Cast Irons of Messrs.

α 70	No. 2. Carron	Cold	Dark gray	Green	7·107
α 71	No. 2. Caedtallon.	Hot	Dull gray	Green	7·030
α 72	No. 2. Carron	Hot	Bright gray	Green	7·081
α 73	No. 2. Caedtallon.	Cold	Dull gray	Green	7·020
α 74	No. 1. Buffery	Hot	Dull gray	Green	7·063
α 75	No. 1. Milton	Hot	Dark gray	Green	7·073
α 76	No. 1. Elsecar	Cold	Bright gray.	Green	7·097

Box α. No. 1. Class No. 12. Gray Cast Iron.

α 77	⅓ No. 1. Calder. ⅓ No. 2. Pentwyn. ⅓ Scrap.	Hot	Close bright gray	Green	7·138

Welsh Cast Iron. Chilled.

6.	7.	8.	9.	10.	11.	12.	13.
Dimensions of Specimen.	Weight of Specimen in Grains.	Weight of Specimen after 387 days' exposure.	Total loss by Corrosion in 387 days.	Loss of Weight per square inch of Surface.	Loss of Weight referred to Standard Bar.	Weight of Water absorbed.	Character of Corrosion.
in. in. in.							
5 × 5 × 1	41990	41538	452	6·45	·608	0·	Uniform P.
5 × 5 × 1	43830	43251	579	8·27	·780	0·	Tubercular.

Staffordshire Cast Iron. Chilled.

5 × 5 × 1	42870	42395	475	6·78	·640	0·	Uniform.
5 × 5 × 1	44290	43868	422	6·03	·569	0·	Tubercular.

Irish Cast Iron. Chilled.

5 × 5 × 1	42790	42296	494	7·06	·666	0·	Uniform P.
5 × 5 × 1	42757	42288	469	6·70	·632	0·	Tubercular.

Mixed Cast Irons.

5 × 5 × 1	43259	42875	384	5.48	·517	5·0	Tubercular.
5 × 5 × 1	42522	41970	552	7·88	·734	0·	Tubercular.
5 × 5 × 5	41589	41140	449	6·41	·605	0·	Tubercular.

Fairbairn's and Hodgkinson's Experiments on Cohesion.

3 × 1·25 × 1·25	9132	8926	206	11·40	1·075	0·	Uniform P.
4 × 1 × 1	7504	7332	172	9·55	·901	0·	Uniform.
4 × 1 × 1	7231	7061	170	9·44	·891	0·	Uniform P.
4 × 1 × 1	7877	7733	144	8·00	·755	0·	Uniform P.
4 × 1 × 1	7454	7301	153	8·50	·802	0·	Uniform P.
4 × 1 × 1	7960	7826	134	7·44	·702	0·	Uniform.
4 × 1 × 1	7370	7215	155	8·61	·812	0·	Uniform P.

Skin removed by Planing.

5 × 5 × ·75	34130	33595	535	8·23	·776	0·	Uniform.

Box α. No. 1. Class No. 13. Gray Cast Iron.

1.	2.		3.	4.	5.
No. of Experiment and mark of Specimen.	Commercial Character of Iron.	Hot or Cold Blast.	External Character of Fracture.	How Cast.	Specific Gravity of Specimen $S=\frac{Ws}{w}$.
α 78	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot Hot	Close bright gray	Green	7·168
α 79	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot Hot	Close bright gray	Green	7·168
α 80	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot Hot	Close bright gray	Green	7·168
α 81	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot Hot	Close bright gray	Green	7·168
α 82	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot Hot	Close bright gray	Green	7·168

Supplementary Table.

No. of Experiment and mark of Specimen.	Protective Paint or Varnish.	State of Covering after 387 days' exposure.
α 78	Caoutchouc varnish.	Rusted off in spots and partly removed...
α 78	Best white-lead paint	Rusted in spots; oil partially removed ...
α 79	Copal varnish	Varnish no longer visible
α 79	Asphaltum varnish	Varnish no longer visible
α 80	Mastich varnish	Coated thinly with extremely hard rust ...
α 80	Swedish tar	Coat of thin rust; coating gone
α 81	3 parts wax + 2 parts tallow. ...	Coating changed into adipocere
α 81	Coal-tar, laid on hot	Coating still visible, with some lustre
α 82	Turpentine varnish.	Varnish scarcely visible.
α 82	Drying oil.	Varnish not visible.

protected by Paints or Varnishes.

6.	7.	8.	9.	10.	11.	12.	13.
Dimensions of Specimen.	Weight of Specimen in Grains.	Weight of Specimen after 387 days' exposure.	Total loss by Corrosion in 387 days.	Loss of Weight per square inch of Surface.	Loss of Weight referred to Standard Bar.	Weight of Water absorbed.	Character of Corrosion.
in. in. in.							
5 × 5 × 1	42580	42143	437	6·24	·589	0·	... ...
5 × 5 × 1	42664	42490	174	2·48	·234	0·	... ...
5 × 5 × 1	41958	41691	267	3·81	·359	0·	... ...
5 × 5 × 1	42721	42466	255	3·64	·343	0·	... ...
5 × 5 × 1	42293	41950	343	4·90	·462	0·	... ...

Box α. No. 1. Class No. 13.

Condition of Surface of Specimen after 387 days' exposure.	Order of Protective Power.	
Corroded in spots, with blotches of plumbago	9	
Corroded in spots; no plumbago formed	10	
Skin of the iron unbroken	2	
Skin of the iron unbroken	1	
Skin not broken into pits; no plumbago	6	
Skin unbroken; no plumbago	5	
Skin sound, only corroded at the edges	3	
Corroded in spots, with tubercles of oxide	4	
Corroded at edges and in pits; plumbago	7	
Corroded at edges and in pits; plumbago	8	

TABLE

Box β. No. 2. containing Specimens of Cast and

Sunk and moored in the foul Sea Water, close to the mouth of the Great Kings-
flood-tide. Bottom soft putrid mud. Temperature of water from 46°
o'clock P.M. on the 3rd of August, 1838. Weighed and landed on the 26th
the 13th of January, and now immersed. Specific gravity of water at

Box β. No. 2. Class No. 1.

1.	2.		3.	4.	5.
No. of Experiment and mark of Specimen.	Commercial Character of Iron.	Hot or Cold Blast.	External Character of Fracture.	How Cast.	Specific Gravity of Specimen $S = \frac{W s}{w}$.
β 1	No. 1. Calder	Hot	Dark gray	Green	7·027
β 2	No. 1. Calder	Hot	Mottled	Chilled	7·079

Box β. No. 2. Class No. 2.

β 3	No. 2. Pentwyn	Hot	Mottled	Green	7·017
β 4	No. 2. Pentwyn	Hot	Silvery	Chilled	7·129

Box β. No. 2. Class No. 3.

β 5	No. 2. Apedale.	Cold	Mottled	Green	7·268
β 6	No. 2. Apedale.	Cold	Silvery	Chilled	7·603

Box β. No. 2. Class No. 4.

β 7	No. 3. Arigna...................... ..	Cold	Dull gray	Green	7·141
β 8	No. 3. Arigna........................	Cold	Mottled	Chilled	7·308

Box β. No. 2. Class No. 5.

β 9	Hardest procurable. Old firebars, &c.	....	Silvery crystals	Chilled	7·624
β 10	{ ½ No. 1. Calder .... + ½ No. 2. Pentwyn. .... }	Hot Hot	Close dull gray	Green	6·978
β 11	{ ½ No. 2. Arigna...................... + ½ No. 2. Pentwyn .... }	Cold Hot	Close dull gray	Green	7·050

No. II.

Wrought Iron immersed in Foul Sea Water.

town Main Sewer. Depth of water two feet at ebb, and from eight to twelve at Fahr. to 58° Fahr. Receives fresh water during heavy rains. Sunk at 4 of August, 1839, at the same hour; thus immersed 387 days. Sunk again on Mouth of Sewer = 1027·70 filtered.

Scotch Cast Irons.

6.	7.	8.	9.	10.	11.	12.	13.
Dimensions of Specimen.	Weight of Specimen in Grains.	Weight of Specimen after 387 days' exposure.	Total loss by Corrosion in 387 days.	Loss of Weight per square inch of Surface.	Loss of Weight referred to Standard Bar.	Weight of Water absorbed.	Character of Corrosion.
in. in. in.							
5 × 5 × 1	42895	42674	221	3·15	·297	0·	Uniform P.
5 × 5 × 1	43636	43046	590	8·42	·794	0·	Tubercular.

Welsh Cast Iron.

5 × 5 × 1	42309	42160	149	2·13	·201	0·	Uniform P.
5 × 5 × 1	43689	43032	657	9·38	·885	0·	Local.

Staffordshire Iron.

5 × 5 × 1	42291	42237	54	0·77	·073	0·	Uniform.
5 × 5 × 1	43749	43596	153	2·19	·207	0·	Local.

Irish Cast Iron.

5 × 5 × 1	42107	41985	122	1·74	·164	0·	Uniform P.
5 × 5 × 1	43155	42357	798	11·40	1·075	0·	Local.

Mixed or alloyed Cast Irons.

5 × 5 × 1	43193	43051	142	2·03	·192	2·0	Tubercular.
5 × 5 × 1	42232	42051	181	2·58	·243	0·	Local.
5 × 5 × 1	42215	42029	186	2·65	·250	0·	Local.

Box β. No. 2. Class No. 6.

1.	2.		3.	4.	5.
No. of Experiment and mark of Specimen.	Commercial Character of Iron.	Hot or Cold Blast.	External Character of Fracture.	How Cast.	Specific Gravity of Specimen $S=\frac{W s}{w}$.
β 12	No. 2. Doulais. Common bar....	....	Fibrous.	Green	7·587

Box β. No. 2. Class No. 7.

β 13	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·138

Box β. No. 2. Class No. 8.

β 14	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
β 15	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
β 16	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
β 17	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
β 18	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168

Supplementary Table.

No. of Experiment and mark of Specimen.	Protective Paint or Varnish.	State of Covering after 387 days' exposure.
β 14	Caoutchouc varnish	Varnish not visible ....
β 14	Best white-lead paint......................	Paint gone ....
β 15	Copal varnish	Varnish not visible ....
β 15	Asphaltum varnish......................	Varnish still perceptible ....
β 16	Mastic varnish	Varnish not visible ....
β 16	Swedish tar	Scarcely any remaining ....
β 17	Three parts wax + two parts tallow	Converted into adipocere......................
β 17	Coal-tar, laid on hot	Still perceptible ....
β 18	Turpentine varnish	Varnish not visible ....
β 18	Drying oil	Not visible ....

Standard Bar Wrought Iron.

6. Dimensions of Specimen.	7. Weight of Specimen in Grains.	8. Weight of Specimen after 387 days' exposure.	9. Total loss by Corrosion in 387 days.	10. Loss of Weight per square inch of Surface.	11. Loss of weight referred to Standard Bar.	12. Weight of Water absorbed.	13. Character of Corrosion.
in. in. in. 4·875 × 3 × ·875	23977	23436	541	12·57	1·186	0·	Uniform str.

Gray Cast Iron. Skin removed by planing.

5 × 5 × ·75	34131	33150	981	13·55	1·278	0·	Uniform.

Gray Cast Iron, protected by Paints or Varnishes.

5 × 5 × 1	43050	42071	979	13·98	1·319	0·	”
5 × 5 × 1	42940	42295	645	7·22	·681	0·	”
5 × 5 × 1	41668	41257	411	5·87	·554	0·	”
5 × 5 × 1	41568	41288	280	4·00	·377	0·	”
5 × 5 × 1	42480	42166	314	4·48	·623	0·	”

Box β. No. 2. Class No. 8.

Condition of Surface of Specimen after 387 days' exposure.	Order of Protective Power.	
Skin unbroken, rusty	9	
Skin unbroken, rusty	10	
Skin sound, soft in spots	8	
Skin sound, hard rust	7	
Skin sound, hard rust	6	
Skin sound, hard rust in spots	5	
Skin sound, and blue rusty in spots	2	
Skin sound, hard rust	1	
Skin sound, hard rust	3	
Skin sound, hard rust	4	

TABLE

Box γ. No. 3. containing Specimens of Cast and Wrought
110° to

Sunk in the Plate-iron Hot Water Cistern of the Dublin and Kingstown
24 inches. Heated by circulation of water from a boiler. Temperature
Taken out and removed in consequence of alterations in the arrangements
immersed 117 days. Specific gravity of water at 60° Fahr. = 1027·80.

Box γ. No. 3. Class No. 1.

1.	2.		3.	4.	5.
No. of Experiment and mark of Specimen.	Commercial Character of Iron.	Hot or Cold Blast.	External Character of Fracture.	How Cast.	Specific Gravity of Specimen $S = \frac{W s}{w}$.
γ 1	No. 1. Calder	Hot	Dark gray	Green	7·027
γ 2	No. 1. Calder	Hot	Mottled	Chilled	7·079

Box γ. No. 3. Class No. 2

γ 3	No. 2. Pentwyn	Hot	Mottled	Green	7·017
γ 4	No. 2. Pentwyn	Hot	Silvery	Chilled	7·129

Box γ. No. 3. Class No. 3

γ 5	No. 2. Apedale	Cold	Mottled	Green	7·268
γ 6	No. 2. Apedale	Cold	Silvery	Chilled	7·603

Box γ. No. 3. Class No. 4

γ 7	No. 3. Arigna	Cold	Dull gray	Green	7·141
γ 8	No. 3. Arigna	Cold	Mottled	Chilled	7·308

Box γ. No. 3. Class No. 5

γ 9	Hardest procurable. Old fire-bars, &c.	....	Silvery crystals	Chilled	7·624
γ 10	½ Calder. No. 1. + ½ Pentwyn. No. 2.	Hot Hot	Close dull gray	Green	6·978
γ 11	½ No. 2. Arigna + ½ No. 2. Pentwyn	Cold Hot	Close dull gray	Green	7·050

No. III.

Iron immersed in clear Sea Water at Temperature from 125° Fahr.

Railway Company's Baths at Salt Hill, near Kingstown. Depth of water nearly constant at 115° Fahr. Sunk on the 6th of August, 1838, at 4 o'clock P.M. of the Baths, on the 1st of December, 1838, at same hour, having thus been

Scotch Cast Iron.

6.	7.	8.	9.	10.	11.	12.	13.
Dimensions of Specimen.	Weight of Specimen in Grains.	Weight of Specimen after 117 days' exposure.	Total loss by Corrosion in 117 days.	Loss of Weight per square inch of Surface.	Loss of Weight referred to Standard Bar.	Weight of Water absorbed.	Character of Corrosion.
in. in. in.							
5 × 5 × 1	43167	43149	18	0·257	·803	0·	Uniform.
5 × 5 × 1	44109	43939	170	2·43	·759	0·	Local.

Welsh Cast Iron.

5 × 5 × 1	42320	42239	81	1·15	·359	0·	Uniform.
5 × 5 × 1	43363	43239	124	1·77	·553	0·	Local.

Staffordshire Cast Iron.

5 × 5 × 1	43805	43735	70	1·00	·312	0·	Local.
5 × 5 × 1	43710	43562	148	2·10	·656	0·	Local.

Irish Cast Iron.

5 × 5 × 1	41805	41745	60	0·85	·265	0·	Uniform.
5 × 5 × 1	43651	43465	186	2·65	·827	0·	Local.

Mixed or alloyed Cast Irons.

5 × 5 × 1	43326	43315	11	0·16	·050	0·	Tubercular.
5 × 5 × 1	42337	42241	96	1·37	·427	0·	Local.
5 × 5 × 1	41433	41341	92	1·31	·409	0·	Local.

Box γ. No. 3. Class No. 6.

1.	2.		3.	4.	5.
No. of Experiment and mark of Specimen.	Commercial Character of Iron.	Hot or Cold Blast.	External Character of Fracture.	How Cast.	Specific Gravity of Specimen $S=\frac{Ws}{w}$.
γ 12	No. 2. Doulais. Common bar ...	....	Fibrous	Green	7·587

Box γ. No. 3. Class No. 7. Gray Cast Iron.

γ 13	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·138

Box γ. No. 3. Class No. 8. Gray Cast Iron,

γ 14	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
γ 15	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
γ 16	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
γ 17	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
γ 18	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168

Supplementary Table γ.

No. of Experiment and mark of Specimen.	Protective Paint or Varnish.	State of Covering after 117 days' exposure.
γ 14	Caoutchouc varnish	Varnish not visible ....
γ 14	Best white-lead paint................	Paint stripped off in places................
γ 15	Copal varnish	Varnish not visible. ....
γ 15	Asphaltum varnish....................	Varnish scarcely visible. ....
γ 16	Mastic varnish	Varnish not visible. ....
γ 16	Swedish tar...........................	A trace still remaining ....
γ 17	3 parts wax and 2 parts tallow ...	Converted into adipocere................
γ 17	Coal-tar, laid on hot	Still visible in some places ....
γ 18	Turpentine varnish...................	Varnish not visible ....
γ 18	Drying oil	Not visible................

Standard bar of Wrought Iron.

6. Dimensions of Specimen.	7. Weight of Specimen in Grains.	8. Weight of Specimen after 117 days' exposure.	9. Total loss by Corrosion in 117 days.	10. Loss of Weight per square inch of Surface.	11. Loss of Weight referred to Standard Bar.	12. Weight of Water absorbed.	13. Character of Corrosion.
in. in. in. 5 × 3 × ·875	24464	24274	190	4·318	1·35	0·	Unif. striated.

Skin removed by planing.

5 × 5 × ·75	34024	33750	274	4·21	1·31	0·	Uniform.

protected by Paints or Varnishes.

5 × 5 × 1	42618	42594	24	0·34	·106	0·	„ „
5 × 5 × 1	42673	42644	29	0·41	·127	0·	„ „
5 × 5 × 1	42457	42399	58	0·83	·259	0·	„ „
5 × 5 × 1	42075	42007	68	0·97	·303	0·	„ „
5 × 5 × 1	42094	42004	90	1·28	·368	0·	„ „

Box No. 3. Class No. 8.

Condition of surface of Specimen after 117 days' exposure.	Order of Protective Power.	
Uniform rusting. Surface hard	1	
Rusted in spots. Hard. No plumbago	4	
Skin sound. Minute cavities	2	
Skin sound. Hard rust uniformly	3	
Skin sound. Hard uniform rust.	5	
Skin sound. Uniform rust	6	
Skin still fresh in parts. Rusted in pits	8	
Rusted in spots. Plumbago in spots	7	
Plumbago in various spots	9	
Pitted in places. Hard rust uniformly	10	

TABLE

Box ১. No. 4. containing Specimens of Cast and Wrought

Sunk and moored in the mid-stream of the river Liffey, at Dublin, opposite and from fifteen to twenty feet at flood-tide. The water fresh at ebb-tide, from 36° Fahr. to 61° Fahr. Sunk on the 6th of August, 1838, at five hour, having been immersed for 383 days. Again sunk in same place at water = 1002·27.

Box ১. No. 4. Class No. 1.

1.	2.		3.	4.	5.
No. of Experiment and mark of Specimen.	Commercial Character of Iron.	Hot or Cold Blast.	External Character of Fracture.	How Cast.	Specific Gravity of Specimen $S=\frac{W s}{w}$.
১ 1	No. 1. Calder	Hot	Dark gray	Green	7·027
১ 2	No. 1. Calder	Hot	Mottled	Chilled	7·079

Box ১. No. 4. Class No. 2.

১ 3	No. 2. Pentwyn	Hot	Mottled	Green	7·017
১ 4	No. 2. Pentwyn	Hot	Silvery	Chilled	7·129

Box ১. No. 4. Class No. 3.

১ 5	No. 2. Apedale.	Cold	Mottled	Green	7·268
১ 6	No. 2. Apedale.	Cold	Silvery	Chilled	7·603

Box ১. No. 4. Class No. 4.

১ 7	No. 3. Arigna	Cold	Dull gray	Green	7·141
১ 8	No. 3. Arigna	Cold	Mottled	Chilled	7·308

Box ১. No. 4. Class No. 5.

১ 9	Hardest procurable. Old firebars, &c.	......	Silvery crystals	Chilled	7·624
১ 10	½ Calder No. 1. + ½ Pentwyn No. 2.	Hot / Hot	Close dull gray	Green	6·978
১ 11	½ No. 2. Arigna. + ½ No. 2. Pentwyn.	Cold / Hot	Close dull gray	Green	7·050

No. IV.

Iron, immersed in Foul River Water, within the tidal limits.

the junction of the Poddle River therewith. Depth of water four feet at ebb, and very brackish at flood. Bottom soft putrid mud. Temperature of water o'clock P.M. Weighed and landed again on the 24th of August, 1839, at same one o'clock P.M., January 13th, 1840, and now immersed. Specific gravity of

Scotch Cast Iron.

6. Dimensions of Specimen.	7. Weight of Specimen in Grains.	8. Weight of Specimen after 383 days' exposure.	9. Total loss by Corrosion in 383 days.	10. Loss of Weight per square inch of Surface.	11. Loss of Weight referred to Standard Bar.	12. Weight of Water absorbed.	13. Character of Corrosion.
in. in. in.							
5 × 5 × 1	41449	41145	304	4·34	·417	0·	Local P.
5 × 5 × 1	43295	42885	410	5·85	·562	0·	Tubercular.

Welsh Cast Iron.

5 × 5 × 1	42462	42181	281	4·01	·378	0·	Local P.
5 × 5 × 1	43333	42903	430	6·14	·590	0·	Tubercular.

Staffordshire Cast Iron.

5 × 5 × 1	44976	44857	119	1·70	·163	0·	Tubercular.
5 × 5 × 1	43760	43478	282	4·03	·373	0·	Tubercular.

Irish Cast Iron.

5 × 5 × 1	40741	40305	436	6·23	·599	0·	Local P.
5 × 5 × 1	42675	42241	434	6·20	·598	0·	Tubercular.

Mixed or alloyed Cast Irons.

5 × 5 × 1	44799	44473	326	4·65	·447	0·	Tubercular.
5 × 5 × 1	42454	42147	307	4·38	·421	0·	Tubercular.
5 × 5 × 1	42318	41981	337	4·81	·462	0·	Tubercular.

Box δ. No. 4. Class No. 6.

1. No. of Experiment and mark of Specimen.	2. Commercial Character of Iron.	Hot or Cold Blast.	3. External Character of Fracture.	4. How Cast.	5. Specific Gravity of Specimen $S=\frac{Ws}{w}$.
δ 12	No. 2. Doulais. Common bar......	....	Fibrous	,,	7·587

Box δ. No. 4. Class No. 7.

δ 13	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·138

Box δ. No. 4. Class No. 8.

δ 14	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
δ 15	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
δ 16	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
δ 17	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168
δ 18	$\frac{1}{3}$ No. 1. Calder + $\frac{1}{3}$ No. 2. Pentwyn + $\frac{1}{3}$ Scrap	Hot	Close bright gray	Green	7·168

Supplementary Table.

No. of Experiment and mark of Specimen.	Protective Paint or Varnish.	State of Covering after 383 days' exposure.
δ 14	Caoutchouc varnish	Varnish not visible ....
δ 14	Best white-lead paint......................	Paint removed in spots ....
δ 15	Copal varnish	Varnish not visible ....
δ 15	Asphaltum varnish	Varnish not visible ....
δ 16	Mastic varnish	Varnish not visible ....
δ 16	Swedish tar	No longer visible ....
δ 17	Three parts wax + two parts tallow	Gone, or changed into adipocere .....
δ 17	Coal-tar, laid on hot	Still lustrous and black ....
δ 18	Turpentine varnish	Varnish not visible ....
δ 18	Drying oil	Not visible..................................

Standard Bar Wrought Iron.

6.	7.	8.	9.	10.	11.	12.	13.
Dimensions of Specimen.	Weight of Specimen in Grains.	Weight of Specimen after 383 days' exposure.	Total loss by Corrosion in 383 days.	Loss of Weight per square inch of Surface.	Loss of Weight referred to Standard Bar.	Weight of Water absorbed.	Character of Corrosion.
in. in. in. 5 × 3 × ·875	24380	24062	318	7·227	·694	0·	Unif. striated.

Gray Cast Iron. Skin removed by planing.

5 × 5 × ·75	34114	33674	440	6·77	·651	0·	Uniform.

Gray Cast Iron, protected by Paints or Varnishes.

5 × 5 × 1	42238	42008	230	3·28	·315	0·	"
5 × 5 × 1	42293	42124	169	2·41	·231	0·	"
5 × 5 × 1	41865	41582	283	4·04	·388	0·	"
5 × 5 × 1	42973	42790	183	2·61	·251	0·	"
5 × 5 × 1	42150	41940	210	3·00	·289	0·	"

Box 8. No. 4. Class No. 8.

Condition of Surface of Specimen after 383 days' exposure.	Order of Protective Power.	
Corroded in pits with plumbago	8	
Skin sound. Hard rust in spots	7	
Skin uniform. Coat of hard rust	1	
Skin uniform. Coat of hard rust	2	
Thick coat of tubercular rust	9	
Soft in spots, with plumbago	10	
Skin sound. Blue rust in spots	4	
Skin sound. Superficial rust in spots	3	
Skin sound. Hard uniform rust	5	
Skin sound. Hard uniform rust	6	

TABLE

Box ε. No. 5. containing Specimens of Cast and Wrought

Sunk in clear, unpolluted water of the river Liffey, above the tidal limits, stream, varying with season from three to six feet in depth. Temperature on the 4th of August, 1838, at five o'clock P.M. Weighed again, and days. Again sunk at one o'clock P.M., January the 13th, 1840, and now

Box ε. No. 5. Class No. 1.

1.	2.		3.	4.	5.
No. of Experiment and mark of Specimen.	Commercial Character of Iron.	Hot or Cold Blast.	External Character of Fracture.	How Cast.	Specific Gravity of Specimen $S=\frac{Ws}{w}$.
ε 1	No. 1. Calder	Hot	Dark gray	Green	7·027
ε 2	No. 1. Calder	Hot	Mottled	Chilled	7·079

Box ε. No. 5. Class No. 2.

ε 3	No. 2. Pentwyn.	Hot	Mottled	Green	7·017
ε 4	No. 2. Pentwyn.	Hot	Silvery	Chilled	7·129

Box ε. No. 5. Class No. 3.

ε 5	No. 2. Apedale.	Cold	Mottled	Green	7·268
ε 6	No. 2. Apedale.	Cold	Silvery	Chilled	7·603

Box ε. No. 5. Class No. 4

ε 7	No. 3. Arigna	Cold	Dull gray	Green	7·141
ε 8	No. 3. Arigna	Cold	Silvery	Chilled	7·308

Box ε. No. 5. Class No. 5

ε 9	Hardest procurable. Old fire-bars, &c.	......	Silvery crystals	Chilled	7·624
ε 10	$\frac{1}{2}$ No. 1. Calder + $\frac{1}{2}$ No. 2. Pentwyn	Hot Hot	Close dull gray	Green	6·978
ε 11	$\frac{1}{2}$ No. 2. Arigna + $\frac{1}{2}$ No. 2. Pentwyn	Cold Hot	Close dull gray	Green	7·050

No. V.

Iron, immersed in the clear Fresh Water of the river Liffey.

within the premises of the Royal Military Hospital, Kilmainham, in a running
very variable, from 32° Fahr. to 68° Fahr. Bottom of fine granite sand. Sunk
landed on the 20th of August, 1839, at same hour. Hence immersed for 381
immersed. Specific gravity of water = 1001·39.

Scotch Cast Iron.

6.	7.	8.	9.	10.	11.	12.	13.
Dimensions of Specimen.	Weight of Specimen in Grains.	Weight of Specimen after 381 days' exposure.	Total loss by Corrosion in 381 days.	Loss of Weight per square inch of Surface.	Loss of Weight referred to Standard Bar.	Weight of Water absorbed.	Character of Corrosion.
in. in. in.							
5 × 5 × 1	42994	42940	54	0·77	·074	0·	Uniform.
5 × 5 × 1	43579	43493	86	1·22	·116	0·	Tubercular.

Welsh Cast Iron.

5 × 5 × 1	42562	42485	77	1·10	·104	0·	Uniform.
5 × 5 × 1	43025	42923	102	1·45	·139	4·0	Tubercular.

Staffordshire Cast Iron.

5 × 5 × 1	43534	43457	77	1·10	·104	0·	Tubercular.
5 × 5 × 1	44174	44095	79	1·13	·109	0·	Tubercular.

Irish Cast Iron.

5 × 5 × 1	43099	43024	75	1·07	·103	0·	Uniform.
5 × 5 × 1	43963	43835	128	1·82	·175	0·	Tubercular.

Mixed or alloyed Cast Irons.

5 × 5 × 1	44204	44125	79	1·13	·109	0·	Tubercular.
5 × 5 × 1	43638	43581	57	0·81	·078	0·	Tubercular.
5 × 5 × 1	43060	42975	85	1·21	·116	0·	Tubercular.

Box ε. No. 5. Class No. 6.

1.	2.		3.	4.	5.
No. of Experiment and mark of Specimen.	Commercial Character of Iron.	Hot or Cold Blast.	External Character of Fracture.	How Cast.	Specific Gravity of Specimen $S=\frac{W s}{w}$.
ε 12	No. 2. Doulais. Common bar	....	Fibrous	"	7·587

Box ε. No. 5. Class No. 7. Gray Cast Iron.

ε 13	⅓ No. 1. Calder.................. + ⅓ No. 2. Pentwyn + ⅓ Scrap	Hot	Close bright gray	Green	7·138

Box ε. No. 5. Class No. 8. Gray Cast Iron.

ε 14	⅓ No. 1. Calder + ⅓ No. 2. Pentwyn + ⅓ Scrap	Hot	Close bright gray	Green	7·168
ε 15	⅓ No. 1. Calder + ⅓ No. 2. Pentwyn + ⅓ Scrap	Hot	Close bright gray	Green	7·168
ε 16	⅓ No. 1. Calder + ⅓ No. 2. Pentwyn + ⅓ Scrap	Hot	Close bright gray	Green	7·168
ε 17	⅓ No. 1. Calder + ⅓ No. 2. Pentwyn + ⅓ Scrap	Hot	Close bright gray	Green	7·168
ε 18	⅓ No. 1. Calder + ⅓ No. 2. Pentwyn + ⅓ Scrap	Hot	Close bright gray	Green	7·168

Supplementary Table. Box ε

No. of Experiment and mark of Specimen.	Protective Paint or Varnish.	State of Covering after 381 days' exposure.
ε 14	Caoutchouc varnish	Varnish not visible ....
ε 14	Best white-lead paint	Paint visible; oil partly gone ....
ε 15	Copal varnish	Varnish not visible ....
ε 15	Asphaltum varnish	Varnish scarcely visible ....
ε 16	Mastic varnish	Varnish not visible ....
ε 16	Swedish tar	Scarcely visible ....
ε 17	3 parts wax + 2 parts tallow	Gone in spots. Changed to adipocere .....
ε 17	Coal-tar, laid on hot	Still black and lustrous ....
ε 18	Turpentine varnish	Not visible ....
ε 18	Drying oil	Not visible ....

Standard Bar of Wrought Iron.

6. Dimensions of Specimen.	7. Weight of Specimen in Grains.	8. Weight of Specimen after 381 days' exposure.	9. Total loss by Corrosion in 381 days.	10. Loss of Weight per square inch of Surface.	11. Loss of Weight referred to Standard Bar.	12. Weight of Water absorbed.	13. Character of Corrosion.
in. in. in. 5·1375×3×·875	24484	24426	58	1·287	·124	0·	Unif. striated.

Skin removed by planing.

5 × 5 × ·875	34088	33922	166	2·55	·245	0·	Uniform.

protected by Paints or Varnishes.

5 × 5 × 1	43064	43015	49	0·70	·067	0·	"
5 × 5 × 1	42162	42139	23	0·33	·031	0·	"
5 × 5 × 1	42107	42052	55	0·78	·075	0·	"
5 × 5 × 1	44277	44260	17	0·24	·023	0·	"
5 × 5 × 1	42015	41989	26	0·37	·035	0·	"

No. 5. Class No. 8.

Condition of Surface of Specimen after 381 days' exposure.	Order of Protective Power.	
Rust in spots. Minute cavities	7	
Uniform coat of soft rust	8	
Skin sound. Blue rust in spots	4	
Skin sound. Rusty in spots	3	
Skin unbroken. Uniform rust	10	
Skin unbroken. Uniform rust	9	
Skin sound. Rusty in spots	2	
Scarcely any visible rust	1	
Hard coat of skin. Buff rust	5	
Hard coat of skin. Buff rust	6	

Table VI.

General Comparison of preceding results of the Action of Air and Water, under the five conditions of experiment, on various Specimens of Cast and Wrought Iron of one inch thick, all reduced to a common period of immersion of 387 days.

			α.		β.		γ.		δ.		ϵ.		Average.
No.	Denomination of Iron.	Commercial Number.	Loss per unit of Surface.	Index of Corrosion.	Loss per unit of Surface.	Index of Corrosion.	Loss per unit of Surface.	Index of Corrosion.	Loss per unit of Surface.	Index of Corrosion.	Loss per unit of Surface.	Index of Corrosion.	Loss in all waters per square inch of Surface.
1.	Calder. Hot	No. 1.	6·11	·576	3·15	·297	0·815	·077	4·38	·413	0·78	·074	5·047
2.	Calder. Hot, chilled	No. 1.	7·65	·722	8·42	·794	8·03	·760	5·90	·556	1·24	·117	6·248
3.	Pentwyn. Hot....................................	No. 2.	6·45	·608	2·13	·201	3·80	·380	4·05	·382	1·12	·116	3·510
4.	Pentwyn. Hot, chilled	No. 2.	8·27	·780	9·38	·885	5·85	·551	6·20	·585	1·47	·138	6·234
5.	Apedale. Hot	No. 2.	6·78	·640	0·77	·073	3·30	·311	1·71	·161	1·12	·106	2·736
6.	Apedale. Hot, chilled	No. 2.	6·03	·569	2·19	·207	6·94	·654	4·07	·384	1·15	·108	4·076
7.	Arigna. Cold	No. 3.	7·06	·666	1·74	·164	2·81	·265	6·29	·593	1·09	·103	3·798
8.	Arigna. Cold, chilled	No. 3.	6·70	·632	11·40	1·075	8·76	·826	6·26	·591	1·85	·174	6·994
9.	Hardest procurable. Chilled................	,,	5·48	·517	2·03	·192	0·53	·050	4·69	·442	1·15	·108	2·776
10.	½ Calder No. 1. + ½ Pentwyn, No. 2. ...	,,	7·88	·734	2·58	·243	4·53	·427	4·42	·417	0·82	·077	4·046
11.	½ Arigna No. 2. + ½ Pentwyn, No. 2. ...	,,	6·41	·605	2·65	·250	4·33	·408	4·85	·457	1·23	·115	3·874
12.	Wrought Iron Standard Bar	,,	10·636	1·000	12·57	1·186	14·28	1·347	7·30	·688	1·31	·123	9·219
13.	Cast Iron. Skin removed by planing......	,,	8·23	·776	13·55	1·278	13·92	1·313	6·83	·644	2·59	·235	9·024
14.	Cast Irons protected by paints or varnishes, as referred to in the Supplementary Tables preceding............	,,	6·24	·589	13·98	1·319	1·12	·105	3·31	·312	0·71	·067	5·072
15.		,,	2·48	·234	7·22	·681	1·03	·098	2·43	·229	0·33	·031	2·698
16.		,,	3·81	·359	5·87	·554	2·75	·259	4·08	·385	0·79	·074	5·460
17.		,,	3·64	·343	4·00	·377	3·20	·302	2·63	·248	0·24	·023	2·742
18.		,,	4·90	·462	4·48	·623	4·23	·399	3·03	·286	0·37	·035	3·402

Table VII.

Deduced from the foregoing Table VI., showing the Average Loss of all varieties of Cast Iron, &c., experimented on in each of the five conditions of immersion for a period of 387 days, on one square inch of surface.

Condition of Iron.	α.	β.	γ.	δ.	ϵ.
Chilled Cast Iron	6·826	6·684	6·025	5·478	1·372
Cast in Green Sand...............	6·781	2·170	3·264	4·283	1·027
No. 2. Bar Iron. Standard ...	10·636	12·570	14·280	7·300	1·310
Cast Iron; Skin removed	8·230	13·550	13·920	6·830	2·590
Cast Iron; Surface protected...	4·214	7·110	2·466	3·096	0·488

Table VIII.

Of the Average Amount of Corrosion in Clear Sea Water, of various Cast and Wrought Irons, at the end of *One Century*, upon one superficial foot of surface, deduced from results of Table No. I.

No.	Class of Iron.	Average loss of Weight per superficial foot in 387 days.	Deduced average loss of Weight per superficial foot in a period of one century.	Approximate depth of Corrosion in one century due to this amount of loss.
		grains avoir.	lbs. avoir.	inch.
1.	Welsh Cast Iron. Hot and cold	859·968	11·58	0·306
2.	Irish Cast Iron. Cold......................	860·400	11·59	0·306
3.	Mixed Cast Irons. Scotch and Welsh; Irish and Welsh, &c. ...	948·960	12·78	0·337
4.	Scotch Cast Iron. Cold, and chiefly hot blast	1067·680	14·38	0·379
5.	Staffordshire, Shropshire and Gloucestershire Cast Irons. Hot and cold	1083·744	14·60	0·385
6.	Gray Cast Iron, mixed. Skin removed by planing	1185·120	15·97	0·419
7.	Derbyshire and Yorkshire Cast Irons. Hot and cold	1212·480	16·34	0·431
8.	Wrought Iron. Standard Bar. No. 2. Doulais	1531·584	20·56	0·543

Table of Experiments on the Amount of Action of Sea Water on Cast Iron these Metals, all exposing equal surfaces.

Exposed Surface of Zinc, Copper or Alloy, = 1·99 square inch.

No. of Experiment.	Atomic Constitution of Alloy.	Specific Gravity of Alloy.	Atomic Weight of Alloy.	Weight of piece previous to immersion.	Weight of piece after immersion for 1579 hours.	Total loss of Weight.
1.	Cu	8·667	31·6	504·90	504·84	0·06
2.	Zn + 10 Cu	8·605	348·3	576·70	576·64	0·06
3.	Zn + 9 Cu	8·607	316·7	555·99	555·93	0·06
4.	Zn + 8 Cu	8·633	285·1	560·17	560·13	0·04
5.	Zn + 7 Cu	8·587	253·4	530·86	530·85	0·01
6.	Zn + 6 Cu	8·591	221·9	556·20	556·20	0·00
7.	Zn + 5 Cu	8·415	190·3	499·10	498·72	0·38
8.	Zn + 4 Cu	8·488	158·7	507·24	507·22	0·02
9.	Zn + 3 Cu	8·397	127·1	468·36	468·30	0·06
10.	Zn + 2 Cu	8·299	95·5	497·33	497·33	0·00
11.	Zn + Cu	8·230	63·9	491·57	491·57	0·00
12.	2 Zn + Cu	8·283	96·2	482·24	482·14	0·10
13.	17 Zn + 8 Cu	7·721	801·9	349·09	348·92	0·17
14.	18 Zn + 8 Cu	7·836	834·2	387·40	386·34	1·06
15.	19 Zn + 8 Cu	8·019	866·5	350·50	350·13	0·37
16.	20 Zn + 8 Cu	7·603	898·8	391·70	391·14	0·56
17.	21 Zn + 8 Cu	8·058	931·1	353·80	353·14	0·66
18.	22 Zn + 8 Cu	7·882	963·4	334·08	333·52	0·56
19.	23 Zn + 8 Cu	7·443	995·7	356·24	355·73	0·51
20.	3 Zn + Cu	7·449	128·5	428·27	426·46	1·81
21.	4 Zn + Cu	7·371	160·8	440·39	438·90	1·49
22.	5 Zn + Cu	6·605	193·1	420·26	418·40	1·86
23.	Zn	6·895	32·3	425·85	422·90	2·95
24.	Fe	7·138	...	...	...	...

TABLE No. X.—Cast Iron, in presence of Tin and

Exposed Surface of Alloys = 1·99 square inch.

Table of Experiments on the Amount of Action of Sea Water on Cast Iron these Metals, all exposing equal Surfaces.

No. of Experiment.	Atomic Constitution of Alloy.	Specific Gravity of Alloy.	Atomic Weight of Alloy.	Weight of piece previous to immersion.	Weight of piece after immersion for 364 hours.	Total loss of Weight.
1.	Cu	8·667	31·6	498·25	498·23	·02
2.	Sn + 10 Cu	8·561	374·9	551·10	551·10	·00
3.	Sn + 9 Cu	8·162	343·3	511·10	511·04	·06
4.	Sn + 8 Cu	8·459	311·7	501·76	501·76	·00
5.	Sn + 7 Cu	8·728	280·1	529·79	529·75	·04
6.	Sn + 6 Cu	8·750	248·5	515·00	514·96	·04
7.	Sn + 5 Cu	8·575	216·9	556·27	556·11	·06
8.	Sn + 4 Cu	8·400	185·3	518·36	518·34	·02
9.	Sn + 3 Cu	8·539	153·7	474·39	474·20	·09
10.	Sn + 2 Cu	8·416	122·1	528·20	528·10	·00
11.	Sn + Cu	8·056	90·5	480·03	479·93	·00
12.	2 Sn + Cu	7·387	149·4	492·29	492·23	·06
13.	3 Sn + Cu	7·447	208·3	454·88	454·88	·00
14.	4 Sn + Cu	7·472	267·2	457·75	457·72	·03
15.	5 Sn + Cu	7·742	326·1	448·21	448·20	·01
16.	Sn	7·291	58·9	415·80	415·74	·06
17.	Fe.	7·138	...	...	...	...

in Voltaic Circuit, with Zinc, with Copper, and with various Atomic Alloys of

Exposed surface of Cast Iron = 3·07 square inches.

Weight of Cast Iron previous to immersion.	Weight after immersion for 1579 hours.	Total loss of Weight.	Loss of Weight per square inch of surface in 387 days.	Loss of Weight per square inch of surface in 387 days, referred to result of α 77.	
903·19	899·97	3·22	6·174	11·37	
903·19	900·15	3·04	5·821	10·72	
903·19	900·33	2·86	5·468	10·08	
903·19	899·92	3·37	6·450	11·88	
903·19	899·44	3·75	7·173	13·21	maximum.
903·19	900·10	3·09	5·880	10·83	
903·19	900·23	2·96	5·594	10·30	
903·19	900·49	2·70	5·174	9·53	
903·19	900·12	3·07	5·880	10·83	
903·19	900·16	3·03	5·762	10·61	
903·19	900·30	2·89	5·527	10·18	
903·19	899·92	3·27	6·232	11·48	
903·19	900·62	2·57	4·939	9·09	
903·19	901·00	2·19	4·174	7·69	
903·19	901·19	2·00	3·822	7·11	
903·19	902·90	0·29	0·553	1·02	
903·19	903·00	0·19	0·364	0·67	
903·19	903·02	0·17	0·323	0·59	
903·19	903·19	0·00	0·000	0·00	
903·19	903·19	0·00	0·000	0·00	
903·19	903·19	0·00	0·000	0·00	minima.
903·19	903·19	0·00	0·000	0·00	
903·19	903·19	0·00	0·000	0·00	
903·19	900·86	2·33	4·468	8·23	= corrosion of α 77.

Copper, immersed in clear Sea Water.

Exposed Surface of Cast Iron = 3·07 square inches.

in Voltaic Circuit, with Tin, with Copper, and with various Atomic Alloys of

Weight of Cast Iron before immersion.	Weight after immersion for 364 hours.	Total loss of Weight.	Loss of Weight per square inch of surface in 387 days.	Loss of Weight per square inch of surface in 387 days, referred to α 77.	
892·55	891·84	0·71	5·894	11·22	minimum.
892·55	891·45	1·10	9·136	17·41	
892·55	891·24	1·31	10·881	21·45	
892·55	891·27	1·28	10·631	20·25	
892·55	891·36	1·19	9·884	18·82	
892·55	890·82	1·73	14·369	27·38	
892·55	890·80	1·75	14·535	27·71	
892·55	891·30	1·25	10·382	19·78	
892·55	891·70	0·85	7·060	13·45	
892·55	891·61	0·94	7·807	14·89	
892·55	890·82	1·73	14·369	27·38	
892·55	890·80	1·75	14·535	27·71	
892·55	891·71	0·84	6·977	13·32	
892·55	890·90	1·65	13·705	26·12	
892·55	891·02	1·53	12·708	24·22	
892·55	890·77	1·78	14·785	38·19	maximum.
892·55	892·03	0·52	4·319	8·23	Corrosion of α77.

No.	Class of Iron.	Hot or Cold.	Commercial No.	Fracture.
1.	Apedale	Cold	No. 2.	Silvery
2.	Hardest procurable	....	Scrap	,,
3.	Gray Cast Iron, of varnish covering	....	,,	,,
4.	Pentwyn.	Hot	No. 2.	,,
5.	Calder.	Hot	No. 4.	,,
6.	Shotts	Hot	No. 4.	,,
7.	Doulais. (Finery pig)	Hot	No. 4.	,,
8.	Arigna	Cold	No. 1.	Micaceous
9.	Burchill's	Cold	No. 1.	,,
10.	Muirkirk	Hot	No. 2.	,,
11.	Pentwyn. (Peculiar)	Hot	No. 1.	,,
12.	Arigna	Cold	No. 3.	Mottled
13.	Apedale. (Cylinder Iron)	Hot	No. 2.	,,
14.	Pentwyn	Hot	No. 2.	,,
15.	Calder, No. 1 + Pentwyn, No. 2 + Scrap	....	,,	,,
16.	Gray Cast Iron. Skin removed	....	,,	,,
17.	Monkland	Hot	No. 4.	,,
18.	Clyde	Cold	No. 1.	,,
19.	Parkfield	Cold	No. 1.	,,
20.	Apedale	Hot	No. 1.	,,
21.	Calder.	Hot	No. 1.	,,
22.	Arigna, $\frac{1}{2}$. Scrap, $\frac{1}{2}$	....	,,	,,
23.	Calder, $\frac{1}{2}$. Scrap, $\frac{1}{2}$	....	,,	Bright gray
24.	Gartsherry	Hot	No. 2.	,,
25.	Shotts.	Hot	No. 2.	,,
26.	Arigna	Cold	No. 3.	,,
27.	Gartsherry	Hot	No. 1.	,,
28.	Shotts.	Hot	No. 3.	,,
29.	Varteg Hill	Hot	No. 2.	,,
30.	Calder	Hot	No. 3.	,,
31.	Summerlie	Hot	No. 2.	,,
32.	Madeley Wood	Cold	No. 1.	,,
33.	Elsecar	Cold	No. 1.	,,
34.	Cinderford.	Cold	No. 1.	,,
35.	Carron.	Hot	No. 2.	,,
36.	Gartsherry	Hot	No. 3.	,,
37.	Muirkirk	Hot	No. 3.	Dull gray
38.	Monkland	Hot	No. 3.	,,
39.	Doulais	Hot	No. 1.	,,
40.	Arigna	Cold	No. 2.	,,
41.	Shotts.	Hot	No. 1.	,,
42.	Lillieshall	Cold	No. 1.	,,
43.	Shotts.	Hot	No. 2.	,,
44.	Caedtalon	Hot	No. 2.	,,
45.	Buffery	Hot	No. 1.	,,
46.	Caedtalon	Cold	No. 2.	,,
47.	Carron	Cold	No. 2.	Dark gray
48.	Doulais	Cold	No. 3.	,,
49.	Doulais	Cold	No. 1.	,,
50.	Blaenavon	Cold	No. 1.	,,
51.	Muirkirk	Cold	No. 2.	,,
52.	Milton	Hot	No. 1.	,,
53.	Calder	Hot	,,	,,
54.	Calder, $\frac{1}{2}$. Pentwyn, $\frac{1}{2}$.	....	,,	,,
55.	Arigna, $\frac{1}{2}$. Pentwyn, $\frac{1}{2}$.	....	,,	,,

Character in Working.	Specific Gravity.	How Cast.	Observations.
Least fusible; thickening rapidly when fluid by a spontaneous "puddling;" crystals vesicular, often crystalline, incapable of being cut by chisel or file; ultimate cohesion a maximum, and elastic range a minimum.	7·603	Chilled	
	7·624	Sand	Maximum density.
	7·624	Chilled	
	7·629	Chilled	
	7·527	Sand	
	7·158	Sand	
	6·378	Sand	Full of microscopic vesicles.
Very soft; feels greasy; peculiar micaceous appearance generally owing to excess of manganese; soils the fingers strongly; crystals large; runs very fluid; contraction large.	7·015	Sand	
	6·928	Sand	
	6·980	Sand	
	7·000	Sand	
Tough and hard; can be with difficulty filed or cut; crystals large and small mixed; sometimes runs thick; contraction on cooling a maximum.	7·308	Chilled	
	7·116	Sand	
	7·017	Sand	
	7·168	Sand	
	7·138	Sand	
	7·294	Sand	
	7·140	Sand	
	7·248	Sand	
	7·268	Sand	
	7·079	Chilled	
	7·134	Chilled	
Toughness and hardness most suitable for working; ultimate cohesion and elastic range generally are balanced most advantageously; crystals uniform; very minute.	6·329	Chilled	Minimum density porous as No. 7.
	7·115	Sand	
	7·152	Sand	
	7·141	Sand	
	7·001	Sand	
	7·183	Sand	
	7·074	Sand	
	7·064	Sand	
	7·156	Sand	
	7·115	Sand	
	7·097	Sand	
	7·049	Sand	
	7·081	Sand	
	7·074	Sand	
Less tough and hard than the preceding; other characters alike; contraction on cooling a minimum.	6·838	Sand	
	7·124	Sand	
	7·164	Sand	
	6·809	Sand	Minimum solid.
	7·109	Sand	
	7·205	Sand	
	7·152	Sand	
	7·030	Sand	
	7·063	Sand	
	7·020	Sand	
Most fusible, remains long fluid; exudes graphite on cooling; soils the fingers; crystals large and lamellar; ultimate cohesion a minimum, and elastic range a maximum.	7·107	Sand	
	7·159	Sand	
	7·192	Sand	
	7·143	Sand	
	7·076	Sand	
	7·073	Sand	
	7·027	Sand	
	6·978	Sand	
	7·050	Sand	

Table No. XII.

Showing the *increase of density* in Castings of large size, due to their Solidification under a considerable head of Metal, varying from two feet to fourteen feet in depth.

No. of Experiment.	Calder Cast Iron. No. 1. Hot blast.			Blaenavon. No. 1. Cold blast.			Apedale. No. 2. Hot blast.			Quam prox. Pressure when fluid in lbs. per square inch.
	Depth of Casting in inches.	Specific Gravity.	First Difference.	Depth of Casting in inches.	Specific Gravity.	First Difference.	Depth of Casting in inches.	Specific Gravity.	First Difference.	
	ins.			ins.			ins.			lbs.
1.	0	6·9551		0	7·0479		0	7·0328		·0
2.	24	6·9633	·0082	24	7·0576	·0097	24	7·0417	·0089	6·4
3.	48	7·0145	·0512	48	7·0777	·0201	48	7·0558	·0141	12·8
4.	72	7·0506	·0361	72	7·0890	·0113	72	7·0669	·0111	19·2
5.	96	7·0642	·0136	96	7·1012	·0122	96	7·0789	·0120	25·6
6.	120	7·0776	·0134	120	7·1148	·0136	120	7·0915	·0126	32·0
7.	144	7·0907	·0131	144	7·1288	·0140	144	7·1046	·0131	38·4
8.	168	7·1035	·0128	168	7·1430	·0142	168	7·1183	·0137	44·8

Table No. XIII.

Showing the decrease of Specific Gravity due to increase of bulk in Iron Castings made from the same sort of Cast Iron, and under similar circumstances.

	Calder. No. 1. Hot Blast.			Blaenavon. No. 1. Cold Blast.			Apedale. No. 2. Hot Blast.		
Mark of Experiment.	Dimensions of Casting.	Specific Gravity.	First Difference.	Dimensions of Casting.	Specific Gravity.	First Difference.	Dimensions of Casting.	Specific Gravity.	First Difference.
	in. in. in.			in. in. in.			in. in. in.		
A.	5 × 5 × 0·25	7·0560		5 × 5 × 0·25	7·1449		5 × 5 × 0·25	7·1876	
			0·0299			0·0015			0·0141
B.	5 × 5 × 0·50	7·0261		5 × 5 × 0·50	7·1464		5 × 5 × 0·50	7·1735	
			0·0366			0·0041			0·0571
C.	5 × 5 × 1	7·0627		5 × 5 × 1	7·1423		5 × 5 × 1	7·1164	
			0·0771			0·0270			0·0358
D.	5 × 5 × 2	6·9856		5 × 5 × 2	7·1153		5 × 5 × 2	7·0806	
			0·0268			0·0211			0·0323
E.	5 × 5 × 4	6·9588		5 × 5 × 4	7·0942		5 × 5 × 4	7·0483	

TABLE No. XIV. Showing the Chemical and Physical Properties

1. No. of Experiment.	2. Chemical Constitution. ε − ε +	3. Composition by Weight per cent. ε − ε +	4. Atomic Weight. H = 1	5. Specific Gravity.	6. Colour, and order of Intensity.	
1	Cu +	100·00 + 0	31·6	8·667	Tile-red.	
2	10 Cu + Zn	90·70 + 9·30	348·3	8·605	Reddish yellow	1
3	9 Cu + Zn	89·80 + 10·20	316·7	8·607	Reddish yellow	2
4	8 Cu + Zn	88·60 + 11·40	285·1	8·633	Reddish yellow	3
5	7 Cu + Zn	87·30 + 12·70	253·4	8·587	Reddish yellow	4
6	6 Cu + Zn	85·40 + 14·60	221·9	8·591	Yellowish red	3
7	5 Cu + Zn	83·02 + 16·98	190·3	8·415	Yellowish red	2
8	4 Cu + Zn	79·65 + 20·35	158·7	8·448	Yellowish red	1
9	3 Cu + Zn	74·58 + 25·42	127·1	8·397	Pale yellow.	
10	2 Cu + Zn	66·18 + 33·82	95·5	8·299	Full yellow	1
11	Cu + Zn	49·47 + 50·53	63·9	8·230	Full yellow	2
12	Cu + 2 Zn	32·85 + 67·15	96·2	8·283	Deep yellow.	
13	8 Cu + 17 Zn	31·52 + 68·48	801·9	7·721	Silver-white	1
14	8 Cu + 18 Zn	30·30 + 69·70	834·2	7·836	Silver-white	2
15	8 Cu + 19 Zn	29·17 + 70·83	866·5	8·019	Silver-gray	3
16	8 Cu + 20 Zn	28·12 + 71·88	898·8	7·603	Ash-gray	3
17	8 Cu + 21 Zn	27·10 + 72·90	931·1	8·058	Silver-gray	2
18	8 Cu + 22 Zn	26·24 + 73·76	963·4	7·882	Silver-gray	1
19	8 Cu + 23 Zn	25·39 + 74·61	995·7	7·443	Ash-gray	4
20	Cu + 3 Zn	24·50 + 75·50	128·5	7·449	Ash-gray	1
21	Cu + 4 Zn	19·65 + 80·35	160·8	7·371	Ash-gray	2
22	Cu + 5 Zn	16·36 + 83·64	193·1	6·605	Very dark gray.	
23	+ Zn	0 + 100·00	32·3	6·895	Bluish gray.	

TABLE No. XV. Showing the Chemical and Physical Properties

1	Cu +	100·00 + 0	31·6	8·667	Tile-red.	
2	10 Cu + Sn	84·29 + 15·71	374·9	8·561	Reddish yellow	1
3	9 Cu + Sn	82·81 + 17·19	343·3	8·462	Reddish yellow	2
4	8 Cu + Sn	81·10 + 18·90	311·7	8·459	Yellowish red	2
5	7 Cu + Sn	78·97 + 21·03	280·1	8·728	Yellowish red	1
6	6 Cu + Sn	76·29 + 23·71	248·5	8·750	Bluish red	1
7	5 Cu + Sn	72·80 + 27·20	216·9	8·575	Bluish red	2
8	4 Cu + Sn	68·21 + 31·79	185·3	8·400	Ash-gray.	
9	3 Cu + Sn	61·69 + 38·31	153·7	8·539	Dark gray.	
10	2 Cu + Sn	51·75 + 48·25	122·1	8·416	Grayish white	1
11	Cu + Sn	34·92 + 65·08	90·5	8·056	Whiter still	2
12	Cu + 2 Sn	21·15 + 78·85	149·4	7·387	Whiter still	3
13	Cu + 3 Sn	15·17 + 84·83	208·3	7·447	Whiter still	4
14	Cu + 4 Sn	11·82 + 88·18	267·2	7·472	Whiter still	5
15	Cu + 5 Sn	9·68 + 90·32	326·1	7·442	Whiter still	6
16	+ Sn	0 + 100·00	58·9	7·291	White	7

Abbreviations used in column 7th to denote character of fracture :—
F.F. Fine Fibrous. C. Conchoidal. V.C. Vitreo-Conchoidal. V. Vitreous.
are = 1. The numbers in column 6th denote intensity of shade of the
specific gravities were determined by the method indicated in Report "On
The ultimate cohesion was determined on prisms of 0·25 of an inch square,
given are those which each prism just sustained for a few seconds before

of the Atomic Alloys of Copper and Zinc of Table No. IX.

7.	8.	9.	10.	11.	12.	13.	14.
Fracture.	Ultimate Cohesion per square inch. Tons.	Order of Ductility.	Order of Malleability, at 60° Fahrenheit.	Order of Hardness, &c.	Order of Fusibility.	Characteristic Properties, in Working, &c.	Relation to Cast Iron, in presence of a solvent, i. e. Sea Water.
E.	24·6	8	1	22	15	Well known.	All these Alloys increase the Corrosion of Cast Iron in Sea Water, when in their presence.
C.C.	12·1	6	13	21	14		
F.C.	11·5	4	11	20	13		
F.C.	12·8	2	10	19	12	Similar, &c. Several of these are malleable at high temperatures.	
F.C.	13·2	9	9	18	11		
F.F.	14·1	5	8	17	10		
F.C.	13·7	11	2	16	9	Bath Metal.	
F.C.	14·7	7	3	15	8	Dutch Brass.	
F.C.	13·1	10	4	14	7	Rolled Sheet Brass.	
F.C.	12·5	3	6	13	6	British Brass.	
C.C.	9·2	12	5	12	6	German Brass.	
C.C.	19·3	1	7	10	6	„ Brass, Watchmakers'.	
C.	2·1	0	22	5	5	Very brittle, Too hard to file or turn, lustre nearly equal to Speculum Metal.	All these Alloys decrease the Corrosion of Cast Iron in Sea Water, when in their presence.
V.C.	2·2	0	23	6	5	Very brittle,	
C.	0·7	0	21	7	5	Very brittle,	
V.	3·2	0	19	3	5	Brittle,	
C.	0·9	0	18	9	5	Brittle,	
C.	0·8	0	20	8	5	Very brittle,	
F.C.	5·9	0	15	1	5	Barely malleable.	
F.C.	3·1	0	16	2	4	Brittle.	
F.C.	1·9	0	14	4	3	White Button Metal.	
F.C.	1·8	0	17	11	2	Brittle.	
T.C.	15·2	13	12	23	1	Brittle, well known.	

of the Atomic Alloys of Copper and Tin of Table No. X.

E.	24·6	1	2	10	16	Well known.	Every Alloy of Cu + Sn increases the corrosive action of Sea Water on Cast Iron, in their presence; the maximum increase is due to Tin.
F.C.	16·1	2	6	8	15	Gun Metal, &c.	
F.C.	15·2	3	7	5	14	Gun Metal, &c.	
F.C.	17·7	4	10	4	13	Gun Metal and Bronze.	
V.C.	13·6	5	11	3	12	Hard Mill Brasses, &c.	
V.	9·7	0	12	2	11	Brittle, All these Alloys found occasionally in Bells, with mixtures of Zn and Pb.	
C.	4·9	0	13	1	10	Brittle,	
C.	0·7	0	14	6	9	Crumbles,	
T.C.	0·5	0	16	7	8	Crumbles,	
V.C.	1·7	0	15	9	7	Brittle	
T.C.	1·4	0	9	11	6	Small Bells, brittle.	
C.C.	3·9	0	8	12	5	„ brittle.	
C.C.	3·1	0	5	13	4	Speculum Metal of Authors.	
C.C.	3·1	8	4	14	3	„ Files, tough.	
E.	2·5	6	3	15	2	„ Files, soft and tough.	
F.	2·7	7	1	16	1	Well known.	

F.C. Fine Crystalline. C.C. Coarse Crystalline. T.C. Tabular Crystalline.
E. Earthy. The maxima of ductility, malleability, hardness, and fusibility,
same colour. The atomic weights are those of the hydrogen scale. The
Action of Air and Water on Iron." Trans. Brit. Assoc. vol. vii. p. 283.
without having been hammered or compressed after being cast. The weights
disruption.

Table XVI.

Specific Gravities of Wrought Iron and Steel, in order from Maximum to Minimum.

1.	2.	3.	4.	5.	6.	
Number.	Commercial Character.	Fracture.	How formed.	Specific Gravity.	Hot or Cold Blast.	
1.	Blister Steel (Roscoe's)	F.C.	Hammered.	7·8461	...	Max. Steel.
2.	Swedish Iron (Dannemora)	F.C.	Rolled.	7·8204	Cold.	Max. Iron.
3.	Spring Steel, Soft (Bradley)	F.C.	Rolled.	7·8067	...	
4.	Cast Steel, Tilted (Roscoe's)	F.C.	Hammered.	7·7983	...	
5.	Damasked Iron; Birmingham	F.	Hammered.	7·7917	Cold.	
6.	Spring Steel, Tempered (Bradley)	F.C.	Rolled.	7·7809	...	
7.	Faggotted Scrap Iron Bar	F. and C.	Hammered.	7·7562	...	
8.	Low Moor Boiler Plate	F.	Rolled.	7·7556	Cold.	
9.	Shear Steel (Roscoe's); soft	F.C.	Hammered.	7·7395	...	
10.	Best English Bar (Bradley)	F.	Rolled.	7·7195	Hot.	
11.	Red Short Bar; Staffordshire	F.	Rolled.	7·6983	Hot.	
12.	Cast Steel; hard as possible (Roscoe's)	F.C.	Hammered.	7·6798	...	
13.	Finished Bar; Forest of Dean, Gloucestershire	F.	Rolled.	7·6795	Hot.	
14.	Common Boiler Plate (Banks)	C.C.	Rolled.	7·6631	Hot.	
15.	Finished Welsh Bar (Doulais)	F.	Rolled.	7·6550	Cold.	
16.	Common Bar; Shropshire; case hardened	F.	Rolled.	7·6533	Cold.	
17.	Cold Short Bar (Burchill's)	C.	Rolled.	7·6514	Hot.	
18.	Puddled Welsh Bar (Doulais)	C.C.	Rolled.	7·6493	Cold.	
19.	Finished Welsh Bar (Doulais)	F.	Rolled.	7·5909	Hot.	
20.	Common Bar; Shropshire; soft	C.	Rolled.	7·5870	Cold.	
21.	Bar Iron of Roscoe's Steel	F.	Hammered.	7·5839	...	
22.	Puddled Bar (Cinderford)	T.C.	Rolled.	7·5470	Cold.	
23.	Puddled Welsh Bar (Doulais)	C.C.	Rolled.	7·5385	Hot.	Min. Iron.
24.	Cast Steel in the Ingot (Roscoe)	C.	Cast.	7·4413	...	Min. Steel. Vesicular.

Report on some Observations on Subterranean Temperature. By Robert Were Fox, *Esq.*

Having already given, through the Philosophical Magazine*, a summary of the observations on subterranean temperature which I had previously published from time to time, I must, in complying with the unexpected invitation of the British Association, necessarily include in the present Report many of the details contained in that memoir.

Early in the year 1815, my friend Joel Lean stated to me his conviction, that the high temperature observed in our mines existed in the earth itself, increasing with the depth; and shortly afterwards his brother Thomas Lean, at our joint request, kindly made many experiments in Huel Abraham Copper Mine, of which he was the manager, in order to test the correctness of this view. The results obtained by him tended to confirm it very unequivocally; and so did another series, made in the same year at my request, in Dolcoath Mine, by John Rule, jun., one of the superintendents. Many other individuals have since obligingly carried on similar observations for me in different mines, all showing that the subterranean temperature increases, in some proportion to the depth from the surface. The ratio of its increase at different depths, and the causes which exercise a greater or less influence upon it, have, however, hitherto been undecided.

I have elsewhere endeavoured to show, that the rate of increase is not so considerable at deeper excavations as at those which are shallower; and the subjoined Tables will, I think, exhibit this point in a satisfactory manner, as far, at least, as the results obtained in some of the mines of Cornwall and Devonshire, which I have published from time to time, may be considered an authority.

* Phil. Mag. 1837, vol. ii. p. 520.

Table I.

Table I.—Showing the Results of Observations on Subterranean the Ratio of its Increase at different Depths. The experiments the deepest levels or accessible parts of the respective mines.

Number.	Date of Observation.	Mines and Localities. { C. stands for Copper Mine. T. ditto Tin ditto. G. for Granite. K. for Killas.	Depth from Surface in Fathoms.	Temperature of Rock, Fahrenheit.
1	1822	South Huel Towan, St. Agnes, C.K. in cistern or reservoir at the bottom	... ...	... ...
2	1827	Huel Wellington, near Camborne, C.K. small stream from Western end of deepest level......	... ...	... ...
3	1827	Ditto ditto ditto Eastern ditto	... ...	... ..
4	1822	East Liscombe, near Tavistock, C.K. in deepest cistern	... ...	... ...
5	1822	Huel Unity-Wood, Gwennap, Tin, K. in ditto......	... ...	... ...
6	1820	*Huel Unity, Gwennap, T. and C.K.	90	66°
7	1820	Ting-Tang, ditto C.K., in the lode	110	68
8	1820	Huel Gorland, ditto C.G.	... ...	... ...
		Means of depths and temperatures...	—— 100·00	—— 67°·00
9	1822	Beer-Alston, Beer-Ferris, Devon, Lead and Silver K., in deepest cistern	... ...	... ...
10	1820	Huel Squire, Gwennap, C.K., in deepest cistern...	... ...	... ...
11	1830	Huel Rose, Newlyn, Lead, K., deepest level	... ...	... ...
12	1824	Chasewater, Chasewater, T.K., in E. end of deepest level	... ...	... ...
13	1824	Ditto ditto, W. end of deepest level	... ...	... ...
14	1824	Huel Trumpet, Wendron, T.G., in deepest level...	... ...	... ...
15	1827	*Huel Jewel, Gwennap, C. and T.G., 40 fathoms to the E. of shaft, and 4 feet from end of level	128	70
16	1827	Ditto ditto, 18 ditto, W. ditto, and 4 feet ditto	138	71
17	1827	Huel Vor, near Helston, T.K. in deepest level, 4 fathoms from shaft	... ...	... ...
18	1822	*Consolidated Mines, Gwennap, C.K. in lode, 16 fathoms E. of Job's shaft	140	72
19	1819	Treskerby, near Redruth, C.G. in lode................	... ...	... ...
20	1822	Poldice, Gwennap, T. and C.K., bottom of Trussel's shaft..	... ..	... ...
21	1822	Ditto ditto ditto of Oppy's shaft ..	... ...	... ...
22	1822	Consolidated Mines, C.K., bottom of Job's ditto...	... ...	... ...
23	1822	Ditto ditto ditto of Taylor's ditto...	150	80
24	1820	Huel Damsel, Gwennap, C.G.	150	70
25	1820	*United Mines, ditto, C.K., end of level N. of Sampson's shaft, and supposed 6 feet from lode	152	74
26	1820	*Ditto ditto ditto, W. of ditto in lode...	152	75
27	1827	Huel Alfred, near Hayle, C.K., E. end of level...	... ...	... ...
28	1827	Ditto ditto ditto, W. ditto...........	... ...	... ...
29	1820	*United Mines, K., in the lode E. of shaft............	160	82
		Means of depths and temperatures	—— 146·25	—— 74·25
		Means of temperature	... ...	70·62
		Deduct mean temperature of climate ...	... ...	50·00
		Means of depths in fathoms, and of excess of temperature above climate	123·12	20·62
		Which being estimated at the depth of 100 fathoms, give	100·00	16·7[illegible]
				50·00
		Computed temperature at	100·00	66°·7[illegible]

Temperature in different Mines in Cornwall and Devonshire, and were, with a few exceptions (distinguished by an asterisk), made in

Depth in Fathoms.	Temperature of Water by Fahrenheit.	Depth in Fathoms.	Temperature of Air, Fahrenheit.	Depth in Fathoms, repeated.	Mean Depth.	Temperature, repeated.	Mean Temperature and Increase.	Ratio of Depth to a given Increase of Temperature = 10°.
45	60°	... ...	... ...	45	... ...	60°	... ...	Surface = 50°
50	57	... ...	... ...	50	... ...	57		
50	58	50	58°·5	50	... ...	58		
82	64	... ...	... ...	82	... ...	64		
86	64	... ...	... ...	86	... ...	64		
				——	62·60	——	60°·60	
							− 50 ·00	
							10 ·60	fms. or 59·05 = 10°
... ...	... ...	... ...	... ...	90	... ...	66		
... ...	... ...	... ...	... ...	110	... ...	68		
... ...	... ...	110	68	110	... ...	68		
—— 62·60	— 60°·60	—— 80·00	— 63°·25					
120	66·5	... ...	... ...	120	... ...	66·5		
120	68	... ...	... ...	120	... ...	68		
... ...	... ...	120	71	120	... ...	71		
128	75	128	76					
128	68	128	74	128	... ...	71		
128	65	128	63	128	... ...	64		
... ...	... ...	... ...	... ...	128	... ...	70		
138	71	... ...	... ...	138	... ...	71		
139	69	136	69	137·5	... ...	69		
... ...	... ...	... ...	... ...	140	... ...	72		
140	76	... ...	... ...	140	... ...	76		
144	78							
144	80							
150	76	... ...	... ...	150	... ...	76		
150	80							
... ...	... ...	... ...	... ...	150	... ...	70		
... ...	... ...	... ...	... ...	152	... ...	74		
... ...	... ...	... ...	... ...	152	... ...	75		
155	70	... ...	... ...	155	... ...	70		
155	67	... ...	... ...	155	... ...	67		
—— 138·50	— 72·11	—— 128·00	— 70·60	——	132·81	...	70·13	
					− 59·05	...	− 60·00	
... ...	66·35	... ...	66·92					
... ...	50·00	... ...	50·00		73·76		10·13	or 72·81 = 10°
100·55	16·35	104·00	16·92					131·86 = 70°
100·00	16·26	100·00	16·27					
... ...	50·00	... ...	50·00					
100·00	66°·26	100·00	66°·27					

Number.	Date of Observation.	Mines and Localities.	Depth in Fathoms.	Temperature of Rock, Fahrenheit.
30	1819	United Mines in bottom of a shaft, K., 8 fathoms S. of lode	... ...	... ...
31	1822	Huel Friendship, near Tavistock, C.K., in deepest level	... ...	... ...
32	1830	Poldice, at bottom of shaft	... ...	... ...
33	1830	Ting Tang, in deepest cistern	... ...	... ...
34	1820	United Mines, in a level	... ...	... ...
35	1837	*Tresavean, Stythians, C., bulb of therm. 2 ft. 10 in. in lode in killas, at 3 fms. from granite	200	76°
36	1837	*Ditto ditto, in killas 10 fms. from granite	200	76
37	1815	Huel Abraham, Crowan, C.K., at bottom	... ...	... ...
38	1824	Stray-Park, Camborne, stream from E. end of deepest level	... ...	... ...
39	1824	Ditto ditto ditto W. ditto	... ...	... ...
40	1830	Huel Vor, T.K., in deepest level	... ...	... ...
41	1837	*Tresavean in granite, 20 fms. from killas, and 12 ft. from lode, bulb 2 ft. 10 in. deep	210	74·2
		Means of depths and temperatures	—— 203·33	—— 75°·40
42	1837	Levant, St. Just., near Land's End, T. and C., end of deepest level W. of engine-shaft, in killas, bulb 3 ft. deep	220	78
43	1837	Ditto, near stream flowing into level E. of engine-shaft, granite	... ...	... ...
44	1837	Ditto, near bottom of engine-shaft in granite, bulb 3 feet deep	230	80
45	1822	Dolcoath, Camborne, C., in deepest level, bulb 3 feet deep in granite, from 19 to 20 months	230	76
46	1815	Ditto, spring of water in bottom of engine-shaft	... ...	... ...
47	1837	*Tresavean in lode in G., 100 fms. from killas, bulb 3 feet deep	234	78·2
48	1819	Dolcoath, water in bottom of engine-shaft	... ...	... ...
49	1837	*Tresavean in lode in G., 60 fms. from killas, bulb 2 ft. 10 in. deep	250	82·5
		Means of depths and temperatures	—— 232·80	—— 78°·94
		Means from 170 to 250 fms. from the surface	218·06	77·17
		Deduct computed temperature at 100 fms. deep, as given before	100·00	66·75
		Difference	118·06	10·42
		Increase of temperature in the second 100 fms.	100·00	= 8·82
		Depth and temperature estimated before	100·00	66·75
		Temperature deduced from the above at 200 fms. deep	200·00	75·°57
50	1837	Tresavean, in lode granite 60 fms. from killas, bulb 2·10 ft. deep	262	82°·5 Too few for an average to be taken from them.
51	1837	Consolidated Mines, K., bulb 3 feet deep in a × level, 24 fms. from lode	290	85·3
52	1837	Ditto ditto ditto 10 ditto	290	86·3
53	1837	Ditto ditto ditto, in the lode	290	92

† No. 32 not included in the mean; and a few other results omitted in the last columns, in consequence of their differing so much from the mean and from the temperature usually found at similar depths.

Depth in Fathoms.	Temperature of Water, Fahrenheit.	Depth in Fathoms.	Temperature of Air, Fahrenheit.	Depth in Fathoms, repeated.	Mean Depth.	Temperature, repeated.	Mean Temperature and Increase.	Ratio of Depth to a given Increase of Temperature = 10°.
170	76°	... ...	... ...	170	... ...	76°		
170	64·5							
176	99†							
178	82							
200	88							
... ...	... ...	... ...	... ...	200	... ...	76		
... ...	... ...	... ...	... ...	200	... ...	76		
200	78	200	78°	200	... ...	78		
200	72	... ...	... ...	200	... ...	72		
200	74	... ...	... ...	200	... ...	74		
209	79	... ...	... ...	209	... ...	79		
... ...	... ...	... ...	... ...	210	... ...	74·2		
—— 190·87	—76°·69	—— 200·00	— 78°·00					
... ...	... ...	... ...	... ...	220	... ...	78		
220	78·5	... ...	... ...	220	... ...	78·5		
... ...	... ...	... ...	... ...	230	... ...	80		
... ...	... ...	... ...	... ...	230	... ...	76		
233	82	... ...	... ...	233	... ...	82		
... ...	... ...	... ...	... ...	234	... ...	78·2		
239	82	... ...	... ...	239	... ...	82		
... ...	... ...	... ...	... ...	250	... ...	82·5		
—— 230·66	— 80°·83							
210·76	78°·76	200·00	78·00					
100·00	66·26	100·00	66·27					
110·76	12·50	100·00	11·73					
100·00	11·27	100·00	11·73					
100·00	66·26	100·00	66·27					
200·00	77°·53	200·00	78°·00					
... ...	... ...	... ...	... ...	262	... ...	82·5		
... ...	... ...	... ...	... ...	290	... ...	85·3		
... ...	... ...	... ...	... ...	290	... ...	86·3		
... ...	... ...	... ...	... ...		225·63		78°·76	
			Less......	... ...	131·86	...	70·00	
			Difference	... ...	93·77	...	8·76	or 107·04 = 10°
Add previous estimated amounts of Depth and Temperature ...								131·86 = 70
Total Depth and Temperature computed								238·90 = 80

Mean results of temp. at 100 fathoms under the surface.

$$
\begin{array}{lcl}
\text{Rock} & = 16\overset{\circ}{}\!\cdot75 + \overset{\circ}{50} = 66\overset{\circ}{}\!\cdot75 \\
\text{Water} & = 16\cdot26 + 50 = 66\cdot26 \\
\text{Air} & = 16\cdot27 + 50 = 66\cdot27 \\
\text{Mean} & \quad 16\cdot43 \qquad\qquad 66\cdot43
\end{array}
$$

At 200 fathoms under the surface.

$$
\begin{array}{lcl}
\text{Rock} & = 8\cdot82 + 66\cdot75 = 75\cdot57 \\
\text{Water} & = 11\cdot27 + 66\cdot26 = 77\cdot53 \\
\text{Air} & = 11\cdot73 + 66\cdot27 = 78\cdot00 \\
\text{Mean} & \quad 10\cdot61 \qquad\qquad 77\cdot03
\end{array}
$$

Table II.

Temperature observed in different parts, but not the deepest, of the following mines, in Cornwall and Devon; Huel Abraham, Dolcoath, United Mines, Treskerby, Huel Squire, Ting Tang, Huel Gorland, Huel Damsel, Chasewater, Huel Unity, Huel Vor, Huel Unity-Wood, Beer Alston, Poldice, Consolidated Mines, Huel Friendship, Huel Maid, Nangiles, North Huel Virgin, Tresavean, etc.

Depth in Fathoms.	Temperature, Fahrenheit.	Mean Results of Temp.	Ratio of Depth to a given Increase of Temperature.		
			Fathoms	Temp.	General Mean
10 to 20	58. + 57. 56. 53.	56°·00			Surface = 50°
20 ... 30	61. 55. 64. + 56. 58.	58·80			
30 ... 40	56. 60. 54. 56. + 61. 62. 56. 62. 61. 57. 69. 57. 55. 60.	58·36			
40 ... 50	58. 60. 60. 60. 60. + 63. 58. 58.	59·62			
50 ... 60	60. 62. 60. 58. + 63. 63. 61. 61. 62. 60. 57.	60·64			
60 ... 70	61. + 62. 64. 61. 61. 59. 68.	62·29			
70 ... 80	64. 62 64. 64. 62. + 64. 66. 70. 65. 64. 64. 68. 67.	64·92			
80 ... 90	66. 64. 63. 64. 66. + 65. 69. 62. 67.	65·11	50·00	60°·72 −50·00	
90 ... 100	58. 67. 72. 64. 65. + 66. 79. 70. 70. 66. 56. 68·5	66·76			fms.
100 ... 110	70. 68. 65. 64. 64. 66. + 68. 68. 69. 65. 66.	66·64	50·00	10·72	or 46·64 = 10
110 ... 120	68. 66. 66. 66·5 + 70. 72. 72. 70. 66. 68. 71.	63·68			
120 ... 130	63. 62. 70. 66. 72. 74. 74. 63. 72. 68. + 71. 76. 73. 74. 62. 73. 70.	6[illegible]·59			
130 ... 140	67. 74·5. 67. 78. 70. 80. 72. + 72. 73. 70. 78. 72. 81. 75.	73·54			
140 ... 150	76. 80. + 74. 72. 80. 71·5.	75·58			
150 ... 160	75. 69. 74. 66. + 70. 68. 73.	70·71			
160 ... 170	64·5. 77. 84. + 71. 71. 73. 66. 76.	72·81	130·00	70°·54	
170 ... 180	75·5. 76. 72. 69. 86. 87. + 74. 72. 74. 72. 73.	75·50	−46·64	60·00	
180 ... 190	75·5. 74. 74. +	74·50	83·36	=10·54	or 79·09 = 10
190 ... 200	+ 74. 71. 71. 74. 77. 78.	74·17			125·73 = 70
			185·00 −125·73	74°·72 70·00	
			59·27	= 4·72	or 125·57 = 10
	Computed from Means of Depth and Temperature				251·30 = 80°

The figures on the left indicate the temperature of the rock, rubbish, or water; those on the right, of the air; in the respective mines, they are divided by +.

The first Table contains results obtained in the *deepest* galleries or accessible parts of mines, a few only excepted, in which cases the experiments were made with great care in the rock at superior levels, and at a distance from other excavations. Some of the reasons for preferring the former to the generality of results derived from the upper parts of mines have been stated on previous occasions, and they appear to be so obvious as to render repetition needless.

The rate of increase of temperature, as it respects the rock or rubbish, and the water and air, appears to have been tolerably consistent. The mean is 16°·43 at 100 fathoms deep, and 27°·03 at 200 fathoms deep; the augmented temperature of the first hundred fathoms being to that of the second hundred fathoms, as 16·43 to 10·60.

Some of the results from which these means are deduced are rather uncommonly high, and probably the general mean temperature observable in our mines would be more nearly represented by their omission, thus reducing both the above means a little; but if this were done, it does not appear that their relations to each other would be essentially altered.

In the last columns are included all the results obtained in the rock, water, and air, with the exception of a few which seem to be in unusual excess, and they give, in round numbers,

A temperature of	60° at	59 fms.	below the surface.
„	70° at	132 „	„
and	80° at	239 „	„

Being an increase of

10°	at 59 fms. deep,	or 1° in 35·4 feet,
of 10	more at 73 fms. deeper,	or 1 in 43·8 feet,
and of 10	„ 114 fms. still deeper,	or 1 in 64·2 feet.

The second Table shows the temperature observed in the rock or rubbish, water, and air, in various mines at different depths, but not in the lowest excavations. It will not therefore, perhaps, be considered to possess much value beyond what is derived from the great number of the results, and the probability that the mean which they indicate may be an approximation to the truth. The figures only are given, without any details, and are to be found in my papers inserted in the Transactions of the Cornwall Geological Society, and in the Philosophical Magazine.

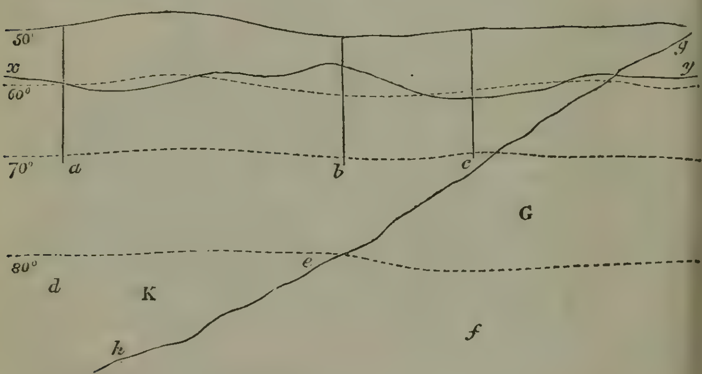
Many of the observations, even in the first Table, may perhaps now be considered very imperfect, having been obtained when the inquiry was in its infancy. The method which I have more recently adopted, of having the bulbs of different thermometers buried at different depths at the bottom of a mine, appears to be as unexceptionable as the circumstances of the case will admit of; but, in fact, I have always considered

that the best experiments on subterranean temperature, influenced as it is by so many disturbing and conflicting causes, can be regarded as affording only approximations to the truth, and, in a greater or less degree, in proportion as they are more or less numerous, and made in different localities.

The second Table exhibits increments of temperature equal to 10° each, at intervals of about 47, 79, and 125 fathoms of descent. The comparative augmentation of temperature at small depths exhibited in this Table, and its reduction at greater ones, may perhaps be more or less attributed to the ascent of warm air and vapour from the deeper galleries of the mines, and the descent of colder currents into these parts.

I have taken the mean temperature at 50° Fahr., and it is, I think, clearly not more than this in the mining districts of Cornwall and Devon, judging from the experiments I have instituted on the temperature of the ground at three different stations, at the depth of three feet, which give a mean of 49°·86* for the year, at a mean elevation of about 240 feet above the level of the sea; and also from the meteorological registers kept in this neighbourhood, some of which appear in the Cornwall Polytechnic Society's Reports and the Annals of Philosophy†.

I add a diagram or section, by way of illustration of the first Table.



* See Transactions of the Cornwall Geolog. Society, vol. iii. pp. 326–328.

† In the Annals of Philosophy, vol. xvi. p. 371, 1820, the mean temperature of eleven years at Penzance is stated to have been only 49°. The elevation of this town above the sea-level is inconsiderable, and perhaps 100 to 200 feet below the average of the mining districts where the experiments were made.

The upper line represents the surface of a given district, and the diagonal one the line of junction of granite and killas. The dotted lines show the mean intervals at which, according to the first Table, there appears to be a progressive augmentation of 10° Fahr.; but the tortuous line *x y* might more properly indicate the very irregular depths at which a given amount of temperature exists, even in the same neighbourhood.

The isothermal lines are represented as having a small inclination downwards as they pass from the killas into the granite, to illustrate the inferior temperature of the latter. The amount of this difference is undoubtedly very variable in different localities, and sometimes little or nothing. I have, in my earlier papers on subterranean temperature, noticed the fact, although I did not ascertain the extent of the difference*, nor have I considered it so high, upon the whole, as Mr. W. J. Henwood has done; but he has investigated this point much more fully than I have, and made numerous experiments in reference to it.

The intervals between the isothermal lines seem to vary much in different places; but I think it will be found to be a general fact, that the temperature increases less rapidly in descending in proportion to the depth of the stations in the mines. If so, the *conducting power of the rocks* cannot, I apprehend, be considered as the immediate or proximate cause of these phænomena at the greatest depths hitherto attained; nor is it to be supposed, that a depth where the heat is transmitted through this medium only will ever be reached by man, seeing that the temperature at the bottom of some deep mines is already almost as great as is compatible with active operations.

I have often suggested, that the differences which are found to exist in the increments of temperature in different places and strata, are principally caused by the circulation of water under the surface; and the tendency of warm water to ascend through cooler portions of that fluid is quite consistent with the fact of the *ratio* of increase being greater at small than at considerable depths. Wherever the facilities are the greatest for the ascent of these currents, such, for instance, as exist in veins, faults or fissures in the strata, and frequently at the junction of different rocks, there the subterranean temperature is usually found in excess, or above the mean. Let the points

* It seems almost needless to remark that, in comparing the subterranean temperature in different rocks, reference should be had to the depth of the stations at which the observations were made.

a, *b*, and *c*, in the section, each represent the deepest part of a mine, all three being in killas. If fissures or veins, pervious to water, be supposed to descend from these points to a much greater depth, where the temperature is considerably higher, it is evident that the warmer water will rise, and the cooler sink and take its place; and thus an excess of temperature will be imparted to *a*, *b*, and *c* by the agency of the circulating water. It matters not whether the ascending currents proceed from *d* in the killas, or *f* in the granite, or through the line of junction *h e*, to *b* or *c*; in any of these cases corresponding effects will be produced, and *a*, *b*, and *c* will be at a higher temperature than other points at equal depths in their vicinity, more or less distant from fissures, veins, etc.; the former differing only in degree according to the depth, or rather temperature of the parts where the currents originate, and the obstacles they meet with in their passage. Nos. 51, 52 and 53, in Table I., may be referred to as examples of this difference. In this case, the vein in the Consolidated Mines, at 290 fathoms deep, was found to be at 92°, whilst the rock at the same depth, and only 10 fathoms from it, was at 86° 3′; and at 24 fathoms from it, 85° 3′. These facts, with others which might be mentioned, seem to show how poor a conductor of heat the rock is, and they give additional support to the views advocated in this Report.

The circulation of water under the surface, and its influence on subterranean temperature, is moreover, I apprehend, promoted by the agency of electricity, which is in such active operation in metalliferous veins*, since it will cause water to pass through many substances that would otherwise be impervious to it. The simplest, and almost the feeblest voltaic combinations, are capable of illustrating this remarkable property, and will transmit water, especially if it contain saline ingredients, through the most tenacious clay, etc., in any direction, either horizontally or vertically.

I will now conclude this Report with the expression of a hope, that the ratio of the increase of subterranean temperature may be more fully investigated, not only in this country but also in others, where the climates are the most dissimilar†, in order to determine the modifications produced by

* I observe, by the Edinburgh New Philosophical Journal, No. 55, that Prof. Reich has detected electric currents in Himmelfahrt Mine, near Freyberg, although they were evidently much less energetic than those prevailing in our mines of copper, etc.

† *Note.*—Might not this object be accomplished, as it respects some of the mines in America, through the instrumentality of the mining companies, if

these circumstances, as well as by the strata and the spheroidal form of the earth, on these phænomena.

requested by the British Association? and I conceive that, in Siberia, Sweden, and other countries, there might be found willing coadjutors in the prosecution of such an investigation so interesting to science. In this Report I have confined myself to my own observations, or those which have been made for me; but I find, on looking over several series of results published by other individuals, that they tend, more or less, to confirm the conclusions at which I have arrived;—that the subterranean temperature does not increase so rapidly in descending, at great depths, as at smaller ones; and it is remarkable, that the observations made long ago, in some mines of Germany, etc., indicate a temperature I think 50 *per cent. less* in the aggregate than the average of the results obtained in the Cornish mines, as far as I am acquainted with them.

Report on the Observations recorded during the Years 1837, 1838, 1839, *and* 1840, *by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham. By* A. Follett Osler, *Esq.*

The records of the Self-registering Anemometer, erected at the Philosophical Institution at Birmingham, are now tabulated for a period of upwards of four years; and though the observations from a single station can neither possess the interest nor value of those we may hope to derive at no distant period from several, yet so little is at present known respecting the laws of the aerial currents in this latitude, that I have ventured to bring forward the few facts at present collected.

The plan adopted first suggested itself in consequence of my friend Mr. Snow Harris having requested me to take out the mean hourly force of the wind without reference to its direction, which he apprehended might show some connection between the wind's movements and the horary oscillations of the barometer*. Considering that this mode of examining the anemometrical records might exhibit other results equally deserving investigation, I pursued the inquiry in the manner set forth in this paper.

The observations are comprised in the years 1837, 1838, 1839, and 1840. The usual plan is adopted of regarding December, January and February as the winter quarter; March, April and May the spring; June, July and August the summer; and September, October and November the autumn.

Having procured a number of sheets of paper, ruled similarly to Table I., I commence with December 1, 1836, and note down the mean force and direction of the wind during each hour of the day, as recorded by the anemometer. The figures express, in pounds avoirdupois, the force exerted by the wind on a surface of one foot square, kept at right angles to the current. I have not noticed the force when less than half a pound is registered, it being difficult to read off a smaller amount with accuracy; and in heavy gales it is not possible to ascertain the mean force of the wind even so nearly as this. Owing to the oscillations of the vane, it is sometimes difficult to ascertain precisely the mean direction; besides which, the instrument occasionally indicates an intermediate place between

* Second Report of the British Association, p. 233.

two points of the compass; it is therefore not always practicable to attain exact accuracy; in all such doubtful cases, I have taken that which, on the whole, appears to be the nearest point.

It must be borne in mind, that it is the force and direction of the wind that this instrument records, and not velocity, which the valuable and ingenious instrument invented by Professor Whewell is intended to register.

But though the oscillations of the vane offer a difficulty for the reason just stated, yet it affords a remarkable distinction between different winds, and even between the same wind at different times. During a north wind, for instance, the vane is generally steady, while during a N.E. and E.N.E. wind the oscillation is frequently considerable. A south wind, too, is sometimes very steady, and at other times the reverse; but not having had time to investigate this peculiarity, I merely mention it for the purpose of inviting attention to the circumstance; as a knowledge of the cause that produces this difference, if fully understood, may prove valuable to the meteorologist.

A sheet on the plan of Table I. having been drawn out for every month during the four years, I proceeded by taking an abstract of each month as shown in Table II., and thus obtained the total of the forces of each wind for the twenty-four hours during the month.

Plate III. fig. 1 is a diagram drawn from the general totals (marked †) in Table III., showing at one view the direction and sum of the forces of the wind for each hour of the day, as registered at Birmingham, during the years 1837–8–9–40.

Plate IV. represents the comparative direction and forces of each wind during the twenty-four hours, distinguishing the quarters of the year. See Table IV.

Plate V. contains diagrams, showing the comparative force and direction of each wind, obtained from the sum of the hourly means in Table III. (marked ‡). See also Table VI.

Plate I. fig. 2 is projected from Table V., and exhibits the comparative force of the wind for each of the twenty-four hours, direction not being regarded. In this Plate the coincidence between the curve of force and of temperature is very remarkable, the temperature preceding the rise of the wind by a short interval.

The whole of these tables must be regarded merely as comparative; I have therefore not considered it necessary or desirable to reduce the total amounts to obtain the mean force per day or per hour, as it would merely add to the labour and sources of error without effecting any equivalent practical

good. Had the anemometer been placed in a more exposed situation, we should have had the same comparative results, but they would probably have been more clearly developed. The principal thing to be aimed at in the selection of a site for such an instrument is, to have it equally exposed to all winds: whether it be on a hill or a plain, is of trifling importance, provided it is not sheltered on either side*.

There are many other facts which I had hoped to have adverted to, such as the law of succession, the mean duration of each wind, and the connection of the currents with the alterations in the state of the barometer, thermometer, and hygrometer, all of which must necessarily furnish interesting subjects for investigation, though I have as yet been unable to devote to them a requisite portion of my time.

* The anemometer from which these observations are taken being placed in the centre of a large town, does not afford such accurate results as would be obtained from an instrument situated beyond the reach of disturbing causes.

TABLE I.—Showing the mode in which the Observations are first taken from the records obtained from the Anemometer.

	A.M.												P.M.											
1836.	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Dec. 1	……	……	……	……	……	……	……	……	……	sw ½	sw 1	wsw ½	wsw ½	wnw 1	wnw 1	wnw 1	w ½	wsw ½	wsw ½	sw ½	……	……	……	ssw 1
2	ssw ½	ssw ½	ssw 1	ssw 1	ssw 1½	ssw 1½	ssw 2	sw 2	sw 2	sw 2	sw 3	sw 2½	sw 3½	sw 3	sw 2½	sw 3	sw 3	sw 2½	wsw 3	wsw 3	sw 2½	sw 2½	wsw 3	……
3	……	……	……	……	……	……	……	……	……	……	……	wnw 3	wnw 4	wnw 3	wnw 2	w 3	w 1½	w 3	w 3	w 3½	w 2½	w 3	sw 2½	w 4
4	wsw 4	wsw 5	wsw 6	wsw 4	wsw 3½	wsw 3½	wsw 3	wsw 3	w 3	w 4	w 4	w 4	wnw 3½	wnw 2½	wnw 2	wnw 2½	wnw 2½	wnw 3	w 2½	w 1	……	w ½	……	w 1
5	w ½	……	……	sw ½	……	wsw 1½	w 1½	w 2	w 2	w 4	w 3	w 4	w 4	w 4	w 3½	w 4	w 5	w 4½	w 4	w 4½	w 3	w 3	w 2	w 2½
6	w 2½	wsw 1½	wsw 1½	……	……	……	sw ½	ssw ½	sw ½	sw 1	sw 1	sw 1	sw 1½	sw 2	sw 1	ssw ½	sw 1½	ssw 1½	ssw 2	ssw 2	ssw 2	ssw 2	ssw 2½	ssw 2
7	ssw 3	ssw 3½	ssw 2	ssw 3	sw 3	sw 1½	sw 2	sw 2	sw 2	ssw 4	ssw 4½	sw 3	sw 4	wsw 4	w 4	w 3½	w 4	w 3½	w 3½	w 4	w 3	w 2½	w 3	wsw 2½
8	ssw 1½	ssw 2	ssw 2½	ssw 3	sw 2	sw 2	sw 1	sw 1½	wsw 1½	wsw 3½	wsw 2	w 2½	w 4	w 4	w 2	w 2	w 1½	w 2	w 1	w 1	sw ½	w ½	w ½	w ½
9	w ½	w ½	w ½	……	sw ½	sw ½	……	……	w ½	w 1	w 1½	w 1½	w 1½	w 2	w 1	……	……	w ½	w ½	w ½	……	……	nw ½	nw ½
10	wnw ½	wnw 1	wnw 1½	w 1	w 1½	w 1	w 1	w 1	w 1½	wsw 1	w 1½	w 1	w 1	wnw 1	……	……	……	w ½	w ½	wnw ½	wnw ½	……	wnw ½	
11	……	……	……	w ½																				
12	……	……	……	……	……	……	……	……	ssc 1½	s 2	s 1	s ½	s ½	ssw 1½	ssw 1½	ssw 2	ssw 2	ssw 3	ssw 3	ssw 4	ssw 3½	wsw 2½	wsw 2	wsw 2
13	sw ½	sw 1	sw 1	sw 2	sw 1½	sw 1½	ssw 1	sw 1½	sw 1	sw 1	sw 1½	sw 1½	w 2	sw 1½	sw 2	sw 1	sw 1	sw 2	sw 2	sw 2	sw 1½	wsw 2	wsw 1½	wsw 1½

16	w 1½	w 2	w 2	w 1	w 1	w 1	wsw 1	w 1	wnw 1	wnw 1	wnw 1½	wnw 2	wnw 2	wnw 1	nw 1	nw 2	wnw ½	......	w ½	w ½	w ½			
17	......	wsw ½	wsw ½	wsw ½	......	sw ½	sw ½	sw ½	ssw ½	ssw ½	ssw ½	ssw ½		sw ½	sw 1	sw 1½	sw 1½	sw 1½	sw 1½	sw 1	sw 1	sw ½	sw ½	sw 1
18	sw 1	wsw 1	wsw 1	wsw ½	w 1½	w 1½	wsw 1	wsw ½	wsw 1	wsw 1	wsw 1	wsw 1	wsw 1	wsw ½	wsw ½	......	wsw ½	w ½	w ½	wsw ½	w ½	w ½	wsw ½	
19	......	......	......	......	ssw ½	ssw ½	ssw 1	sw 1	sw 1	sw 1	sw 1	ssw ½	sw ½	sw 1	sw 1½	sw 1	sw 1½	sw 1½	sw ½	sw ½	sw ½	sw ½		
20	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	wsw ½
21	wsw ½	......	......	......	......	......	......	wnw ½	......	w ½	w ½	......	......	wnw ½	nw ½	nnw 1	nnw 1	nnw 1	nnw 1	nnw 1½	nnw 1			
22	......	nnw ½	......	......	......	......	......	......	......	......	......	wnw ½	wnw ½	wnw 1	wnw 1	wnw ½	wnw 1	wnw 1½	wnw 1½	wnw 1	wnw 1	wnw 2	wnw 2	wnw 2½
23	nw 2	nw 2	w 1	w ½	......	nne 1	nne 1½	nne ½	nne 1	n ½	n ½	nnw 1½	nnw ½	nnw 1	nnw 1	nnw 1	nnw 1½	nnw 1	nnw 1½	nnw 1	...	...	nne 2	
24	nne 1½	nne 1½	ne 1	nne 1	n 1½	n 1	n 1	n ½	n ½	nnw 1	nnw 1	n ½	......	ne ½	nne ½	nne 1	ne 1	ne 1½	ne 2½	ne 2	ne 2½	nne 2	ne 2	
25	nne 1½	nne 1½	nne 1½	nne 1	nne 1	nne 1½	nne 1½	nne 1	nne 2	nne 2	nne 2	nne 2	ne 2	ne 2½	ne 2	ne 2	ene 3	ne 2	ne 2	ne 3	ne 3	ne 3	ne 2	ne 3½
26	ne 3½	ne 3	ne 3½	ene 3	ene 3½	ene 4	ene 4	ene 4½	ene 4	ene 3	ne 3	ne 3½	ne 3½	ne 4	ne 3	ne 3½	ne 4	ne 4½	ne 3	ne 3½	ne 3	ne 2½	ne 2½	ne 2½
27	ne 2	ne 2½	ne 2	ne 2	ne 2	ne 2½	ne 2	ne 2	ne 2	ne 2	ne 2½	ne 2	ne 2	ne 2	ne 2	ene 2	ene 1½	ene 2	ene 1½	ene 1	ene 1	ene 1	ne 1	ne 1
28	ne 1	ne 2	ne 1½	ne 1	ne 1	ne 1	ene 1	ene ½	ne 1	ne 1	ne ½	ne ½	ne ½	nne ½	nne ½	nne ½	nne ½	nne ½	nne ½	nne ½	nne ½	nne ½	nne ½	
29	......	......	......	......	......	......	......	......	......	......	......	......	nne ½	nne ½										
30	......	......	......	......	......	......	n ½	......	......	......	......	......	nne ½											
31	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	nne ½	......	......	......	nne ½

Table II.—Abstract of Table I.

December 1836.

	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
N.	...	...	...	...	1½	1	1½	½	½	½	½	½	...	...	...	...	...	...	...	...	...	...	...	...
N.N.E.	3	3	1½	2	1	2½	3	1½	3	2	2	2	1	1	1	1½	½	½	½	1	½	2½	2½	½
N.E.	6½	7½	8	3	3	3½	2	2	3	3	6	6	8	9	7	5½	5	8	7½	8½	8½	5½	7½	7
E.N.E.	...	...	...	3	3½	4	5	5	4	...	...	...	...	...	...	2	4½	2	1½	1	1	1	...	...
E.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
E.S.E.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
S.E.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
S.S.E.	...	...	...	...	...	...	...	...	1½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
S.	...	...	...	...	...	...	...	...	...	2	1	½	½	...	...	...	...	...	...	...	...	...	...	...
S.S.W.	5	6	5½	7	2	2	4	½	½	4½	5	1	...	1½	1½	2½	3	6	7	8½	8	5	5½	7
S.W.	3	2	2½	4	8½	7	4½	8½	6½	5½	7½	8	9½	8	8	7	8½	7½	4	4	6	3½	3	1
W.S.W.	4½	8	9	5	3½	5	5	5	4½	5½	3	1½	1½	4½	½	...	½	½	3½	3½	...	4½	7	6½
W.	5	2½	3½	3	4	3½	2½	4	7	12	13½	16	15½	10	10½	12½	12½	14½	16	15	9½	10	5½	8
W.N.W.	½	1	1½	...	...	...	...	½	1	1	1½	5½	10	13½	8½	6	4	4½	1½	1½	1½	2	2½	2½
N.W.	2	2	...	...	...	...	...	...	...	...	...	...	...	...	1½	2	2	2	2	...	...	...	½	½
N.N.W.	2	2½	1½	1	1	1	½	½	...	1	1	1½	½	1	1	2	2½	2	2½	4	3	1½	½	1½

TABLE III.—Showing the sum of the forces of each wind during the twenty-four hours for the years 1837–38–39, and 40, distinguishing the months and quarters of the year, and the total forces of each month and each quarter taken collectively.

N.	A.M.												P.M.												Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
Dec. ...	...	...	...	...	1½	1	1½	½	½	½	½	½	...	...	...	...	...	...	...	...	...	...	½	...	7
Jan.......	½	½	½	...	½	...	1	1	½	1	2	1	6	6	6½	5½	4	1	½	1½	3½	4½	3½	1½	52½
Feb. ...	1	1½	1	...	...	...	...	...	...	1	1½	3	3	4	1½	6	4	3½	3½	3	3	3	2½	2	48
*	1½	2	1½	...	2	1	2½	1½	1	2½	4	4½	9	10	8	11½	8	4½	4	4½	6½	7½	6½	3½	‡107½
March ..	...	...	...	...	...	...	...	...	2½	4	7	7½	7	4½	3	5½	5	3½	4½	4½	3½	1½	1	...	64½
April ...	6½	5	1	2½	...	2½	4½	6½	11	9½	9	7	7	12	13	16½	15½	13	8½	18	9½	9½	8	7	202½
May ...	5	4	5	6	5½	1½	3	4½	6½	5	5	7½	7½	11½	9½	7	5	4½	7½	4	3	3	4	3	128
*	11½	9	6	8½	5½	4	7½	11	20	18½	21	22	21½	28	25½	29	25½	21	20½	26½	16	14	13	10	‡395
June ...	...	...	...	...	...	½	½	1	...	...	...	...	...	1	...	...	...	½	½	½	...	½	...	½	5½
July ...	...	...	...	...	...	...	...	...	...	...	...	½	½	½	½	1	½	...	...	...	...	...	...	...	3½
August.	...	...	...	...	...	...	...	...	½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	½
*	...	...	...	...	...	½	½	1	½	...	...	½	½	1½	½	1	½	½	½	½	...	½	...	½	‡9½
Sept. ...	...	...	...	...	...	...	...	...	...	½	1	3	1	1½	1½	...	...	...	...	...	...	...	...	...	8½
Oct. ...	...	...	...	...	...	...	...	...	...	½	...	½	...	...	...	1	2½	3	4	1½	...	...	...	...	13
Nov. ...	...	...	...	...	...	...	...	...	...	...	1	½	½	½	...	...	...	½	1	1	1½	2½	2½	...	11½
*	...	...	...	...	...	...	...	...	...	1	2	4	1½	2	1½	1	2½	3½	5	2½	1½	2½	2½	...	‡33
†Gen. Total.	13	11	7½	8½	7½	5½	10½	13½	21½	22	27	31	32½	41½	35½	42½	36½	29½	30	34	24	24½	22	14	545

† See Plate II. fig. 1. * See Plate III. and Table IV. ‡ See Plate IV. and Table VI.

Table III. (continued.)—1837-8-9-40.

N.N.E.	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. ...	3	3	1½	2	1	2½	3	1½	3	2	2	2	1	1	1	1½	1½	1	½	½	1	3	2½	1	42
Jan. ...	1½	3	1	½	½	½	...	...	½	½	½	2½	3½	5½	5½	1	1	2	½	1	1	1	½	1	34½
Feb. ...	½	½	1	2	1½	1	1	2	1½	3	3½	4½	4	4½	5	1	1½	...	...	½	½	½	½	...	40
*	5	6½	3½	4½	3	4	4	3½	5	5½	6	9	8½	11	11½	3½	4	3	1	2	2½	4½	3½	2	‡116½
March ..	½	1	½	½	½	½	½	1½	3	5	3½	7	8	6	5	5	2½	2½	2½	2	1½	1	...	½	60½
April ...	1½	2½	1½	2	2	2	3½	5½	3	6	3	2½	2	1½	3½	2	4½	2½	1	2	1	2	4	3	64
May ...	7	7	4½	6	6	12	11½	10½	12½	14	13	13	17½	14½	15½	18½	21	15½	13	11	13	9	11½	8	285
*	9	10½	6½	8½	8½	14½	15½	17½	18½	25	19½	22½	27½	22	24	25½	28	20½	16½	15	15½	12	15½	11½	‡409½
June ...	½	½	...	...	½	1	½	1	...	...	...	½	1	...	...	...	½	...	...	½	...	...	...	...	6½
July ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0
Aug. ...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	½	...	½	...	...	...	...	...	...	...	2
*	½	½	...	...	½	1	½	1	...	...	...	½	1	1	½	...	1	...	...	½	...	...	...	...	‡8½
Sept. ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0
Oct. ...	...	...	...	...	...	...	...	½	1½	2½	3	4	3	2	3	1½	½	½	...	...	...	...	...	...	22
Nov. ...	1	½	½	2½	½	...	...	...	1½	3	1½	4½	4	4	2½	3½	1½	2	1½	1½	6½	2	1½	1½	47½
*	1	½	½	2½	½	...	...	½	3	5½	4½	8½	7	6	5½	5	2	2½	1½	1½	6½	2	1½	1½	‡69½
†Gen. Total.	15½	18	10½	15½	12½	19½	20	22½	26½	36	30	40½	44	40	41½	34	35	26	19	19	24½	18½	20½	15	604

† See Plate II. fig. 1. * See Plate III. and Table IV. ‡ See Plate IV. and Table VI.

TABLE III. (continued.)—1837–8–9–40.

N.E.	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. …	6½	7½	8	3	3	3½	2	2	3	3	6	6	8	10	8	6	5	8	7½	8½	8½	5½	5	7	140½
Jan. …	…	…	…	…	…	…	…	…	…	…	…	..	…	…	…	…	…	…	1	½	½	½	1	1	4½
Feb. …	1½	2	2	1	1½	1½	3	½	2	1½	1½	4½	3	2½	2½	3½	4	3	3½	3	3	3	2½	1½	57½
*	8	9½	10	4	4½	5	5	2½	5	4½	7½	10½	11	12½	10½	9½	9	11	12	12	12	9	8½	9½	‡202½
March .	½	1	…	…	½	½	½	1	2	1½	2½	1	2	1½	2	1½	2½	2	2	1½	1½	1	½	1	30
April …	½	1½	1½	1½	1	½	1	1½	7½	8	6½	9½	11½	8	9	8½	5	7½	4	2	4	2½	2	1½	106
May …	…	3	3	4	4	2½	½	½	1	3	6½	10	5½	9½	10½	12	6½	7	6	2½	2	½	½	½	101
*	1	5½	4½	5½	5½	3½	2	3	10½	12½	15½	20½	19	19	21½	22	14	16½	12	6	7½	4	3	3	‡237
June …	1	1	1	…	…	…	…	…	3½	3½	3½	1½	1½	2½	3½	2	2	1½	1½	1½	1½	½	…	…	33
July …	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	½	…	1½	…	…	2
August .	…	…	…	…	…	…	…	…	…	…	2	½	…	…	…	2	1½	1	1	½	½	½	½	1	11
*	1	1	1	…	…	…	…	…	3½	3½	5½	2	1½	2½	3½	4	3½	2½	2½	2½	2	2½	½	1	‡46
Sept. …	…	…	…	..	…	…	…	…	…	½	…	½	½	1	½	…	…	…	…	…	…	…	…	…	3
October.	…	…	…	½	1	2	…	…	..	1½	1½	…	1½	2½	½	½	…	…	…	½	½	…	2	½	15
Nov. …	½	½	…	…	1	…	1	1	2½	…	6½	7	3½	5	5	2	3	4½	4½	3	2	½	½	½	54
*	½	½	…	½	2	2	1	1	2½	2	8	7½	5½	8½	6	2½	3	4½	4½	3½	2½	½	2½	1	‡72
† Gen. Total.	10½	16½	15½	10	12	10½	8	6½	21½	22½	36½	40½	37	42½	41½	38	29½	34½	31	24	24	16	14½	14½	557½

† See Plate II. fig. 1. * See Plate III. and Table IV. ‡ See Plate IV. and Table VI.

TABLE III. (continued.)—1837-8-9-40.

E.N.E.	A.M.												P.M.												Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
Dec. ...	...	...	...	3	3½	4	5	5	...	3½	½	1	1	...	...	2	4½	2	2½	3	2½	2½	2	...	47½
Jan.	7	7½	7	6½	6	3½	3½	3	3	2	3½	1½	2	3½	3½	3½	2½	1	1	3	4	2½	2½	2½	85½
Feb. ...	1½	2	2½	4	4½	6	1½	3	5	7	6½	2	1½	3½	2	1½	1½	4	3½	2½	3	...	...	½	69
	8½	9½	9½	13½	14	13½	10	11	8	12½	10½	4½	4½	7	5½	7	8½	7	7	8½	9½	5	4½	3	202
March...	...	...	...	...	...	...	1½	2	2½	6½	7½	6½	8	8½	7½	8	4½	2½	1½	1	1	1	1	½	71½
April ...	...	...	...	...	...	½	½	1	...	...	...	...	1½	...	...	2	3	1½	1½	1	1	½	...	...	14
May ...	...	...	...	...	...	...	1½	2	2½	1	2½	2½	5	7	3	2½	2	...	1½	...	1½	1½	½	...	36½
	...	...	...	...	...	½	3½	5	5	7½	10	9	14½	15½	10½	12½	9½	4	4½	2	3½	3	1½	½	122
June ...	½	½	½	½	...	...	...	...	...	...	...	2	2	1	½	1	...	...	...	...	...	...	½	½	9½
July ...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	½	½	1	2	1½	1½	...	1	2	12
August .	...	...	...	...	1	½	½	2½	3	3	2½	2½	2½	3	4½	1½	2	2	½	½	1	1	½	...	34½
	2½	½	½	½	1	½	½	2½	3	3	2½	4½	4½	4	5	3	2½	3	2½	2	2½	1	2	2½	56
Sept. ...	...	...	...	...	...	...	...	...	1	1½	1	1½	...	1½	½	1	1½	½	...	...	...	...	...	...	10
Oct.	...	...	...	...	...	...	1	3	4	5½	7	7½	8½	5	4½	3½	2½	2½	1½	½	1	1½	1	1	61
Nov. ...	1½	3	3½	4	5	7	8½	8½	6	9½	6½	5½	5½	5½	5½	8½	4½	2	2	1	½	1	1½	2	108
	1½	3	3½	4	5	7	9½	11½	11	16½	14½	14½	14	12	10½	13	8½	5	3½	1½	1½	2½	2½	3	179
Gen. Total.	12½	13	13½	18	20	21½	23½	30	27	39½	37½	32½	37½	38½	31½	35½	29	19	17½	14	17	11½	10½	9	559

TABLE III. (continued.)—1837-8-9-40.

E.	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. ...	...	...	...	...	...	...	...	1	5	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	7
Jan. ...	2½	2	4½	5½	5½	4½	4	6½	13½	13	12½	10½	11	8½	13½	10½	12	11½	10	8	5	8½	6½	5½	195
Feb. ...	5	5	4½	5	3½	2½	4½	7	7½	13	16½	20½	19½	14½	17	16½	14½	16	13½	12	14½	13	9½	10½	265½
	7½	7	9	10½	9	7	8½	14½	26	26	29	31	30½	23	30½	27	26½	27½	23½	21	19½	21½	16	16	467½
March...	...	...	...	...	...	...	...	...	½	½	...	1	...	½	2	2½	1	½	½	½	...	...	...	...	9½
April ...	½	2	2	1½	1	...	...	...	½	½	1	1½	1½	½	1	...	...	...	1	1	1	...	...	1	17½
May ...	...	...	...	...	...	...	½	1	1½	1½	1½	1½	1½	1	½	...	...	...	...	½	1	...	...	...	12
	½	2	2	1½	1	...	½	1	2½	2½	2½	4	3	2	3½	2½	1	½	1½	2	2	...	...	1	39
June ...	...	...	...	...	...	...	...	...	...	½	...	...	1	1	½	1	½	½	½	1½	1	½	...	...	8½
July ...	...	½	...	...	...	...	½	½	½	1	1	1½	1	½	1	1½	2	2½	1	2	1½	1	1	½	21
August .	...	...	...	...	...	...	...	½	½	2	2½	3	3	2½	2½	3½	3	2	1½	1	½	...	...	...	28
	...	½	...	...	...	...	½	1	1	3½	3½	4½	5	4	4	6	5½	5	3	4½	3	1½	1	½	57½
Sept. ...	...	...	...	...	...	...	...	...	...	1½	2½	1½	4½	2½	2½	2	...	...	...	...	...	...	...	...	17
Oct. ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nov. ...	...	½	½	...	...	...	...	...	...	5	4	4½	4	6	2	1	3½	1	...	1	...	½	1	½	35
	...	½	½	...	...	...	...	...	...	6½	6½	6	8½	8½	4½	3	3½	1	...	1	...	½	1	½	52
Gen. Total.	8	10	11½	12	10	7	9½	16½	29½	38½	41½	45½	47	37½	42½	38½	36½	34	28	28½	24½	23½	18	18	616

TABLE III. (continued.)—1837-8-9-40.

E.S.E.	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. ...	2	½	1	½	...	...	...	...	...	6½	2	1	...	...	1	1½	1	...	...	...	...	...	...	...	17
Jan.	...	...	...	...	...	...	1	1	1½	2	1	1	2	1	1	1	1½	2½	...	...	...	...	...	...	16½
Feb. ...	1½	2	3	3½	4	4½	5½	3	4½	8½	9	6½	9	9½	8½	8½	6	1½	1½	1½	1½	1	2	2½	108½
	3½	2½	4	4	4	4½	6½	4	6	17	12	8½	11	10½	10½	11	8½	4	1½	1½	1½	1	2	2½	142
March...	...	...	...	...	...	...	...	...	...	...	...	2	1	1½	1	...	...	...	...	...	...	...	...	...	5½
April ...	2	1½	1	...	...	2	1½	1½	2	1½	1½	2	...	2	1	1	1	3	½	...	1½	1	...	...	27½
May ...	1	½	...	...	...	...	...	...	...	2	2½	2	3	6½	1	3	1½	5	7	5	5	...	2	1½	48½
	3	2	1	...	...	2	1½	1½	2	3½	4	6	4	10	3	4	2½	8	7½	5	6½	1	2	1½	81½
June ...	½	...	...	½	½	1	2	1½	2	1½	2	3	3½	3½	4	4	5½	5½	6	1½	1½	½	...	½	50½
July	2½	3	2	3	4½	6	8	...	1	2	2	2½	2	1½	1	...	...	...	...	...	2	...	2½	2½	48
Aug. ...	...	...	...	...	...	...	...	...	...	1½	1½	2	1½	1½	...	...	...	...	...	...	...	...	...	...	8
	3	3	2	3½	5	7	10	1½	3	5	5½	7½	7	6½	5	4	5½	5½	6	1½	3½	½	2½	3	106½
Sept. ...	...	½	...	...	1	2½	...	...	...	...	1½	1	1	½	½	2	...	...	...	...	...	...	...	...	10½
Oct.	...	...	...	...	...	...	...	...	...	½	...	...	...	½	...	...	...	...	1½	...	...	...	...	...	2½
Nov. ...	2½	5	5	8½	7	8	4	2	8	4½	5	8	8	12	3	9½	½	3½	1	½	½	½	1	...	107½
	2½	5½	5	8½	8	10½	4	2	8	5	6½	9	9	13	3½	11½	½	3½	2½	½	½	½	1	...	120½
Gen. Total.	12	13	12	16	17	24	22	9	19	30½	28	31	31	40	22	30½	17	21	17½	8½	12	3	7½	7	450½

TABLE III. (continued.)—1837-8-9-40.

S.E.	A.M.												P.M.												Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
Dec. ...	1½	3	2	2	3	2½	1½	1½	2½	3½	1½	4	7	4½	2	3	2½	5	4½	5	6	8½	4	3	83½
Jan. ...	...	...	...	...	1	1½	2½	3½	2	3½	4	1½	2½	4½	3½	2	2	2	4	6	5½	7	5½	1½	65½
Feb. ...	3	3½	3½	2½	2	1½	1½	3½	4½	5	4	4	4½	2½	2½	2½	2	2	3	4½	3½	4	2½	4	76
	4½	6½	5½	4½	6	5½	5½	8½	9	12	9½	9½	14	11½	8	7½	6½	9	11½	15½	15	19½	12	8½	225
March .	2	2	2	...	...	...	...	1½	1½	3½	5½	3½	4½	3	2	1½	1	1½	1	...	1	1	½	2½	41
April ...	...	...	...	3	2	...	...	1	½	½	1½	2	1	1½	½	1	...	...	...	...	...	1	1½	½	17½
May ...	...	...	...	½	1	...	...	1½	1½	½	4	½	1	...	7½	½	...	1	...	½	...	1	...	...	21
	2	2	2	3½	3	...	...	4	3½	4½	11	6	6½	4½	10	3	1	2½	1	½	1	3	2	3	79½
June ...	...	...	...	...	1	1	1½	2½	2	2	2½	2½	2	½	2½	1	...	...	...	2	1½	...	...	...	24½
July ...	...	...	...	...	...	...	...	9	4	1½	2½	3	5	8	6½	½	...	...	4	3	...	2	...	...	49
August .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	...	...	...	...	1	1	1½	11½	6	3½	5	5½	7	8½	9	1½	...	...	4	5	1½	2	...	...	73½
Sept. ...	1	½	...	½	...	...	2½	...	1	1	2½	2½	5	5½	1½	...	1½	½	1	½	...	½	...	...	27½
Oct. ...	...	...	...	...	...	...	...	...	1½	½	1½	1	2	½	2½	3	2½	3	6	5	4½	4½	5½	2	45½
Nov. ...	2½	½	1	1	1½	1	1	1	½	5	7½	3	4	4	12½	8	2	2½	½	...	...	...	3½	8	70½
	3½	1	1	1½	1½	1	3½	1	3	6½	11½	6½	11	10	16½	11	6	6	7½	5½	4½	5	9	10	143½
Gen. Total.	10	9½	8½	9½	11½	7½	10½	25	21½	26½	37	27½	38½	34½	43½	23	13½	17½	24	26½	22	29½	23	21½	521½

TABLE III. (continued.)—1837-8-9-40.

S.S.E.	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. ...	5½	5½	5	3½	2	1	1	3	5	5	8½	13	13	11½	12	11	13	12½	11½	16½	12	7½	11½	10	200
Jan. ...	1	½	...	...	...	...	...	1½	2	3½	...	2½	1	½	...	2½	2	2	2½	1½	4	2	1	4	34
Feb. ...	11	10½	9½	7	7½	6½	7½	7½	3	5½	6	5½	6	8½	9½	4	3½	1	4	9½	10	3½	7½	7½	161½
	17½	16½	14½	10½	9½	7½	8½	12	10	14	14½	21	20	20½	21½	17½	18½	15½	18	27½	26	13	20	21½	395½
March ...	1	1½	1	5½	6	½	½	1	4	2½	2	2½	1	3	3½	3	1½	3½	2½	2½	2½	1	1½	1	54½
April ...	½	1½	1½	3	1½	2	1½	1½	3	...	...	...	½	1	1½	1	...	...	1	2	2	2	2	1½	30½
May......	...	½	...	...	1½	4½	4½	2	2	1½	3	5½	7½	7	½	...	2½	2	...	...	...	...	...	½	45
	1½	3½	2½	8½	9	7	6½	4½	9	4	5	8	9	11	5½	4	4	5½	3½	4½	4½	3	3½	3	130
June ...	4½	½	½	...	...	...	...	...	3	4½	5	4½	6	5½	6½	6½	5	3½	3½	3	3	5	6½	5	81½
July......	...	...	1	1	...	...	2½	1½	11	11½	9½	11	3	4½	6½	6½	11	11	13	4½	...	...	...	...	109
Aug. ...	½	...	3	5	5	6	5	1	2	4	3½	4½	2½	2½	1½	1	...	...	2½	2½	2½	2½	3½	2½	63
	5	½	4½	6	5	6	7½	2½	16	20	18	20	11½	12½	14½	14	16	14½	19	10	5½	7½	10	7½	253½
Sept. ...	1	1	2½	3	2½	2½	2½	5½	7	8	9	½	1½	1½	4½	4	2	½	½	1	3	2	½	...	66
Oct. ...	1	4½	2	1	1	½	½	1½	2	6	3½	5	5½	5	7½	4½	4½	4	3½	2½	1½	½	...	1	68½
Nov. ...	11	10½	12	11	13	7	3½	9½	10½	11½	10½	15	9½	10½	12½	17	8½	10	15	10	7	9½	3½	7	245
	13	16	16½	15	16½	10	6½	16½	19½	25½	23	20½	16½	17	24½	25½	15	14½	19	13½	11½	12	4	8	379½
Gen. Total.	37	36½	38	40	40	30½	29	35½	54½	63½	60½	69½	57	61	66	61	53½	50	59½	55½	47½	35½	37½	40	1158½

TABLE III. (continued.)—1837-8-9-40.

S.	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. ...	3½	5½	5½	7½	9½	5	7	8½	3	10	11	12½	8½	11½	5½	5	5½	4½	5½	1½	2½	3	3½	6	151
Jan. ...	8	12½	8	5½	5	7	13	14½	20½	25½	30½	32	29½	9	8½	8½	8	4½	6	5	6	13	9	11½	300½
Feb. ...	7½	6½	7	9½	12½	9	8½	9	11½	10½	13½	9	8	5½	7	12½	10½	9½	6½	5½	9	13	11	8½	220½
	19	24½	20½	22½	27	21	28½	32	35	46	55	53½	46	26	21	26	24	18½	18	12	17½	29	23½	26	672
March...	2½	5	6	2	1	7	7½	8½	4½	3½	13½	1½	11½	3	1	½	½	...	...	...	...	...	...	...	79
April ...	1½	3	3½	1	...	3	2	3	2	6	7	3½	8½	10½	11	11	8½	7	4	4½	3	...	...	½	104
May ...	2	½	1½	1½	½	1½	3	3½	4½	6	3	4½	4½	5½	7	3	3	2½	2½	3	2	1	2	2½	70½
	6	8½	11	4½	1½	11½	12½	15	11	15½	23½	9½	24½	19	19	14½	12	9½	6½	7½	5	1	2	3	253½
June ...	4½	6	6	2	1½	1	1	2	4	8	9½	14½	13	14	14½	9½	9	9	10	7	5½	7	5½	6	170
July ...	8	7	5	3	7	10½	11½	15	21	23	17½	10	22	23½	19	18	17½	10	6½	9	12½	11½	7½	10	305½
Aug. ...	3	4	1	2	1	2	3	8½	3½	6	7½	14	11	14½	15	10	8	8	3	2	2	4½	6½	7½	147½
	15½	17	12	7	9½	13½	15½	25½	28½	37	34½	38½	46	52	48½	37½	34½	27	19½	18	20	23	19½	23½	623
Sept. ...	1½	2	3	3	4½	4½	5	7½	7	12½	8½	18	14½	19	13½	7½	6	5	4	2	2	6½	2½	1	160½
Oct. ...	2½	4½	5	5	½	½	...	...	2	6½	8½	8	6½	11½	4½	4	12	...	4	3	3	2½	5½	3½	103
Nov. ...	8½	3	1	1½	3	6	9	6	7	6½	6½	7	13	9	8½	9½	22	9	5	12	10	9	8½	9½	190
	12½	9½	9	9½	8	11	14	13½	16	25½	23½	33	34	39½	26½	21	40	14	13	17	15	18	16½	14	453½
Gen. Total.	53	59½	52½	43½	46	57	70½	86	90½	124	136½	134½	150½	136½	115	99	110½	69	57	54½	57½	71	61½	66½	2002

TABLE III. (continued.)—1837-8-9-40.

S.S.W.	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. ...	9	12½	8	7	2½	2	4½	1	2	11½	6½	5½	22½	8½	8½	12	11	14½	12½	9½	9	6½	8½	9½	204½
January.	12½	14½	17½	17½	19½	26½	14	9	8½	4½	7	7	8	32	7	9½	8	18½	9	2½	6	8	17	11	294½
Feb. ...	4½	5	4	3½	3½	5	6½	8	8	11	10½	18	22½	17	13	13½	9	7½	9½	8	9	7	6½	2	212
	26	32	29½	28	25½	33½	25	18	18½	27	24	30½	53	57½	28½	35	28	40½	31	20	24	21½	32	22½	711
March .	½	½	1	...	1	1½	1½	1½	2½	12½	15	9½	4½	11½	14	8	12	17½	8	14½	15½	11	8	8	179½
April ...	...	...	½	1	1½	1½	4½	8	11½	5	3½	10	6½	6½	7	9½	12	10	10	10½	1	1	...	1	122
May ...	...	½	½	1½	½	...	1	2½	2	1½	4½	4	4	5½	8	4	5½	2	½	2	1	1	1½	1	54½
	½	1	2	2½	3	3	7	12	16	19	23	23½	15	23½	29	21½	29½	29½	18½	27	17½	13	9½	10	356
June ...	5	1½	3	2½	4	6	8½	12	13½	14	22½	16	22½	19½	19	14½	15½	11½	11	9½	8½	4	4½	2½	251
July ...	...	1	½	2	4½	4	5	4½	6	7	14½	23	11½	16½	18	12½	9	5	5	2	1½	1½	1	...	155½
August .	9	3	4½	4	3½	3½	3½	2	8	12	11	13½	13	8½	14	13	11½	9	2½	8	8	5	10½	4	184½
	14	5½	8	8½	12	13½	17	18½	27½	33	48	52½	47	44½	51	40	36	25½	18½	19½	18	10½	16	6½	591
Sept. ...	4	9	4	4	3½	2½	4	6	9	11½	18½	13½	19½	13½	14½	15	12	9	8	4½	2	3	2	1½	194
October.	8	5	2	5	4	1	1	4½	4½	10	9	15½	14½	10½	12½	13	8	20	18	12½	12½	14½	12	10½	228
Nov. ...	9½	11	7	5½	9½	14	9	13½	4	9	9	8½	6½	7½	7	4½	2	2½	2½	2½	½	...	1½	2	148½
	21½	25	13	14½	17	17½	14	24	17½	30½	36½	37½	40½	31½	34	32½	22	31½	28½	19½	15	17½	15½	14	570½
Gen. Total.	62	63½	52½	53½	57½	67½	63	72½	79½	109½	131½	144	155½	157	142½	129	115½	127	96½	86	74½	62½	73	53	2228½

TABLE III. (continued.)—1837-8-9-40.

S.W.	A.M.												P.M.												Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
Dec. ...	4	2½	3½	7½	14	12	13½	16	11	10½	12½	13	10½	12½	16½	16½	23½	16½	11½	17½	14	10	7	9	285
January.	30	31½	30½	38½	35½	31½	35	24½	29	33	42	48½	54½	39	49½	33½	15½	10	23½	25½	16	12	14½	14½	717½
Feb. ...	...	...	1½	3½	1½	2½	2½	2½	6	12½	10½	10	14	17	13	12	11	11	4½	4	2½	5	6½	2½	156
	34	34	35½	49½	51	46	51	43	46	56	65	71½	79	68½	79	62	50	37½	39½	47	32½	27	28	26	1158½
March .	8	6½	6½	6½	8½	8	3	4	2½	5	9½	17½	23½	19½	21	26½	25	8	5½	2½	2½	1½	4½	6	231½
April ...	7½	½	...	...	1	1	½	2	3½	7½	9½	7	7½	5	5	3½	3	½	½	2½	13	12½	10	9	112
May ...	4	2½	2	1½	1½	5	6	2½	5	6½	2	4½	2½	1½	2	3½	1	1	1½	1½	...	½	1	1	60
	19½	9½	8½	8	11	14	9½	8½	11	19	21	29	33½	26	28	33½	29	9½	7½	6½	15½	14½	15½	16	403½
June ...	3½	7	9½	3	5	5	6½	10	15½	18½	16½	18	14	11	7	3½	6	5½	1½	1½	2	2½	2½	2½	177½
July ...	½	½	3	1½	...	3	6	7½	5	11	8	10	11½	10	7	10½	13½	6½	3	1	1½	1½	1½	2½	126
August .	8½	7	8	5½	3	4½	5½	6½	6	7½	13½	16	17	17½	15½	18	10½	9½	8	4½	3½	6½	3½	5½	211
	12½	14½	20½	10	8	12½	18	24	26½	37	38	44	42½	38½	29½	32	30	21½	12½	7	7	10½	7½	10½	514½
Sept. ...	9	3	8	8	4	1	3	7	9	4	8	15	10	13	19	23	7	4	5	13	17	10	17	14	231
October.	3	3	5½	2½	6	5	7	4½	5½	8½	12	8	19	14	15	11½	6½	7½	9	5½	6	5	2½	2½	174½
Nov. ...	...	½	1	3½	6½	8	6	3½	7½	14½	11½	17½	20½	19	18	16	15	17	15	13	15½	13	13½	11	266½
	12	6½	14½	14	16½	14	16	15	22	27	31½	40½	49½	46	52	50½	28½	28½	29	31½	38½	28	33	27½	672
Gen. Total.	78	64½	79	81½	86½	86½	94½	90½	105½	139	155½	185	204½	179	188½	178	137½	97	88½	92	93½	80	84	80	2748½

TABLE III. (continued.)—1837–8–9–40.

W.S.W	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. ...	3½	8½	9½	8	5	5	5	5	4½	8½	10	5	5½	8½	3½	½	½	½	6	8½	5	8½	9	2	135½
January.	8½	8	9½	14½	11	11	14	17	13½	8	10	6	11½	15	19½	17½	28½	29	19	18	20	18	15	14½	356½
Feb. ...	11½	7	2	2	3½	3½	3	5	3½	2½	6	5	4½	6	6½	7	3½	1½	4½	3½	4½	7½	5½	10	119
	23½	23½	21	24½	19½	19½	22	27	21½	19	26	16	21½	29½	29½	25	32½	31	29½	30	29½	34	29½	26½	611
March...	5	5	4½	8	2½	2	2	8½	11½	13	12½	13½	13	16	12½	9½	12	8	3	3½	4	4½	1½	1½	177
April ...	...	5½	5½	5½	2½	3	2	6	2	5	6½	4½	3½	4	4	4	3½	3½	1½	½	...	...	1	...	73½
May ...	1	1½	...	...	2½	1	6	8	5	6½	8	4½	4	3½	5	6½	7	4	4	2	1½	½	1½	...	83½
	6	12	10	13½	7½	6	10	22½	18½	24½	27	22½	20½	23½	21½	20	22½	15½	8½	6	5½	5	4	1½	334
June ...	½	1	½	3½	1	2	3	2	1	½	½	1	3½	8½	9	13	11	5	3	2	...	...	...	...	71½
July ...	2½	2½	2½	2	2½	½	2	4½	4½	7½	11	15	14½	15½	12	10	7½	5	3½	2	½	½	3½	1	132½
August .	...	...	...	5	3½	4½	...	3	4½	8½	8	7	8	9	10	7	7½	5½	3	½	½	½	½	...	96
	3	3½	3	10½	7	7	5	9½	10	16½	19½	23	26	33	31	30	26	15½	9½	4½	1	1	4	1	300
Sept. ...	...	...	...	...	...	...	½	½	1	3½	4	5	10	16½	7½	8½	5½	3	1½	1	½	...	2½	...	71
October.	5½	2½	1	5½	1½	5½	3	3½	7½	3	7½	9½	2	6½	5½	6	2½	1	1½	3	9½	4½	9½	11	118
Nov. ...	10	7	7½	7	...	1	2	3	1	4	7½	13½	13	14½	6	1	½	1	1	...	...	1	1	1	103½
	15½	9½	8½	12½	1½	6½	5½	7	9½	10½	19	28	25	37½	19	15½	8½	5	4	4	10	5½	13	12	292½
Gen. Total.	48	48½	42½	61	35½	39	42½	66	59½	70½	91½	89½	93	123½	101	90½	89½	67	51½	44½	46	45½	50½	41	1537½

TABLE III. (continued.)—1837-8-9-40.

W.	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. ...	5	2½	3½	3	4	6	5	6½	11	15½	15½	20½	20	12	12½	15	15	17	17½	15½	16	16	8	8	270½
Jan. ...	10	6	4½	2½	12	8½	10½	6	2	5	13	19	15	16½	9½	7	3	3½	4½	3½	2½	3½	2	3½	173
Feb. ...	1½	5	5½	6	3	3½	6	2	4½	4	4	7	½	2½	5	2	...	...	1½	3½	5½	1	1½	...	75
	16½	13½	13½	11½	19	18	21½	14½	17½	24½	32½	46½	35½	31	27	24	18	20½	23½	22½	24	20½	11½	11½	518½
March...	3	4½	3	1	4	2½	...	½	1	3½	4	4	4	5½	8	5½	3½	3	3	3	2½	2½	3½	3	78
April ...	...	...	½	...	5½	2	2½	6	3½	12	12½	5	5	5½	5½	4	4	4	3	1	½	...	...	...	82
May ...	...	...	1½	2½	...	...	½	...	5½	7	5½	8	10½	5	4½	4	4	5	1½	2	...	...	½	...	67½
	3	4½	5	3½	9½	4½	3	6½	10	22½	22	17	19½	16	18	13½	11½	12	7½	6	3	2½	4	3	227½
June ...	1	1½	...	...	½	½	1½	1	2½	4	4	5	3	4	3	5	2	2½	2	½	...	...	...	½	44
July ...	5	2	3½	3	2½	3	4	4	4½	2½	4	5	5½	6	10	5	4	2	3½	4	6	3½	5	4	101½
Aug. ...	...	...	...	...	...	...	4	4½	5	6½	6	6	5½	5	4	2½	3	2	1½	½	...	...	...	...	56
	6	3½	3½	3	3	3½	9½	9½	12	13	14	16	14	15	17	12½	9	6½	7	5	6	3½	5	4½	201½
Sept. ...	...	...	...	...	...	1	1	2½	4	6	6½	6½	8	6	9	4½	3	1	½	...	...	1	2	½	63
Oct. ...	1½	5	1	1	8	1	1½	...	...	1½	2	5	2½	½	2½	...	...	½	...	3	...	4	...	...	40½
Nov. ...	2	4½	...	1½	1½	½	...	1	4½	...	1	2	½	6	4½	...	1½	½	...	...	...	...	1	1	33½
	3½	9½	1	2½	9½	2½	2½	3½	8½	7½	9½	13½	11	12½	16	4½	4½	2	½	3	...	5	3	1½	137
Gen. Total.	29	31	23	20½	41	28½	36½	34	48	67½	78	93	80	74½	78	54½	43	41	38½	36½	33	31½	23½	20½	1084½

TABLE III. (continued.)—1837–8–9–40.

W.N.W.	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Totals.
Dec. ...	4	2	2	...	...	...	...	1½	1	1½	2	6	10½	14	9	7	4½	5	5½	1½	1½	2	8½	13	102
Jan. ...	4	4½	5	1½	...	...	...	2½	9	6	9	15½	10½	8	5	6	3½	2	3	8	3	6	7½	6	125½
Feb. ...	9	7½	4	2½	3½	5	3½	...	1½	2	3	4½	9½	5½	6	2½	...	4½	2½	2½	2	7	5½	8½	102
	17	14	11	4	3½	5	3½	4	11½	9½	14	26	30½	27½	20	15½	8	11½	11	12	6½	15	21½	27½	329½
March...	2½	2	2	4	4½	4	6	7½	6½	7	6	6½	7	7	6½	6½	5	3½	1½	2	1	1	1	1	101½
April ...	9½	11½	8	5½	7	14	14½	12	15	15½	5	16½	24½	32	33	28	25½	23	20½	16½	12½	11½	11½	10½	383
May ...	...	1	3½	3½	1	1½	1	2½	3	3	4	½	2	5½	6	9	7	3½	1½	1½	1½	1½	1½	...	65
	12	14½	13½	13	12½	19½	21½	22	24½	25½	15	23½	33½	44½	45½	43½	37½	30	23½	20	15	14	14	11½	549½
June ...	1½	1½	2	1½	1½	2	2	2½	2½	3½	3½	2	4½	2	5	4	3	5½	3½	1	½	1	2	2½	60½
July ...	...	...	1	1½	...	...	1	3½	...	...	6	3½	3½	5	5	5	3½	...	...	...	...	...	2	3	43½
Aug. ...	½	1	1½	...	½	½	½	1	2	4	4	5½	5½	7½	6½	4½	3½	1½	½	...	...	½	½	½	52
	2	2½	4½	3	2	2½	3½	7	4½	7½	13½	11	13½	14½	16½	13½	10	7	4	1	½	1½	4½	6	156
Sept. ...	3½	3	5	2½	2	½	...	...	...	1½	1	½	½	...	...	...	...	...	...	...	...	...	...	...	20
Oct. ...	...	...	...	...	...	4	5½	7	6½	5	6	6½	5	5½	7	½	...	...	½	...	2	1	1½	1	64½
Nov. ...	½	1½	2½	2	1	...	...	...	...	1½	2½	2½	2½	2½	2	6½	3	½	5½	4½	1½	2½	1	2	48
	4	4½	7½	4½	3	4½	5½	7	6½	8	9½	9½	8	8	9	7	3	½	6	4½	3½	3½	2½	3	132½
Gen. Total.	35	35½	36½	24½	21	31½	34	40	47	50½	52	70	85½	94½	91	79½	58½	49	44½	37½	25½	34	42½	48	1167½

TABLE III. (continued.)—1837-8-9-40.

N.W.	A.M.												P.M.												Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
Dec. ...	2	3½	...	...	...	...	...	...	...	...	...	½	...	...	1½	2	2	2	2	...	...	...	½	½	16½
Jan. ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	½	½	½	...	1	1½	1	5
Feb. ...	...	...	4	4	6½	4½	4½	7½	7	3½	3½	3½	3½	5½	6½	5½	7½	4	4	3½	½	...	1½	...	90½
	2	3½	4	4	6½	4½	4½	7½	7	3½	3½	4	3½	5½	8	7½	9½	6½	6½	4	½	1	3½	1½	112
March...	3	3	3	1	1	1½	1½	2½	4	5½	9	8	5½	4½	6	6	6	4½	4	3½	6	3	4½	3½	100
April ...	2½	4½	4½	3	4	5½	7½	17	18½	11½	17½	15	13½	4	1½	4	6	4½	3	5	6½	6½	3½	2	171
May ...	2	1½	½	...	1½	1½	2	1½	1½	2½	4	7	5	5½	6	5	4	6	3	3½	4	1	1	2½	72
	7½	9	8	4	6½	8½	11	21	24	19½	30½	30	24	14	13½	15	16	15	10	12	16½	10½	9	8	343
June ...	...	...	...	½	1	1	1½	2½	1½	1	1½	4½	3	2½	3½	3	4	2	1	½	½	...	...	...	35
July ...	½	...	½	...	...	½	1½	1½	2½	4½	4	2½	3	1½	2½	4	3½	2½	2	½	...	½	...	½	38½
Aug. ...	...	...	...	...	...	...	...	...	...	...	...	1	1½	1	1½	...	½	...	...	...	...	...	...	...	5½
	½	...	½	½	1	1½	3	4	4	5½	5½	8	7½	5	7½	7	8	4½	3	1	½	½	...	½	79
Sept. ...	...	...	...	...	...	...	...	...	1	1	1½	1½	1	1½	3	2	½	1	½	...	...	½	...	1	16
Oct. ...	...	2	1½	4½	5½	2½	...	1	2	3	½	1½	3	2½	2	7½	6	5½	4½	4½	3½	2½	2	1	68½
Nov. ...	2	2	...	½	½	3½	2½	1	...	½	1	1	...	...	...	...	...	1	1½	2	3½	4½	5	3½	35½
	2	4	1½	5	6	6	2½	2	3	4½	3	4	4	4	5	9½	6½	7½	6½	6½	7	7½	7	5½	120
Gen. Total.	12	16½	14	13½	20	20½	21	34½	38	33	42½	46	39	28½	34	39	40	33½	26	23½	24½	19½	19½	15½	654

TABLE III. (continued.)—1837-8-9-40.

N.N.W.	A.M.												P.M.												Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
Dec. ...	2	2½	2½	1	1	1	½	½	...	1	1	1½	½	1	1	2	2½	2	2½	4	3	1½	½	1½	36½
Jan. ...	5½	5	4½	4½	3	2½	3	2½	3	4	4½	5	8½	7	6	6	6½	6½	4½	3½	7½	6	4½	4½	118
Feb. ...	1½	1½	1	½	½	½	...	½	½	3	3½	3½	3½	3½	5½	4½	2	1½	1	1	1½	1½	1½	1½	45
	9	9	8	6	4½	4	3½	3½	3½	8	9	10	12½	11½	12½	12½	11	10	8	8½	12	9	6½	7½	199½
March...	1½	1½	2	2	2	1½	2	3½	4½	5½	3½	3½	5½	4	4½	5½	3½	1½	1½	½	½	2½	1	1	64½
April ...	2	1	2½	1	3	1½	2	2½	11	12	15	19	15	14	10½	6½	3½	5½	7½	6	3	2½	2½	1½	150½
May ...	2½	1	1½	1	1	2	3½	6	6½	8	7	5	6	4	3	5½	4½	4½	2	1½	½	3½	3	2	85
	6	3½	6	4	6	5	7½	12	22	25½	25½	27½	26½	22	18	17½	11½	11½	11	8	4	8½	6½	4½	300
June ...	1½	1½	1	1	½	2	4	3	5	4½	3½	3½	5	6	5	4½	4	4	3	2	1½	2	1½	1½	71
July ...	3	1	½	½	½	2	2	2½	3	2	½	1½	1½	...	½	...	1	2	3½	½	½	...	...	1	29½
Aug. ...	...	...	...	...	...	...	...	...	...	½	½	...	...	...	...	...	...	...	...	...	...	...	...	...	1
	4½	2½	1½	1½	1	4	6	5½	8	7	4½	5	6½	6	5½	4½	5	6	6½	2½	2	2	1½	2½	101½
Sept. ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2½	2	½	½	...	...	...	...	6½
Oct. ...	1	½	½	½	...	...	...	...	...	2	6	7	5	3½	3	½	½	...	...	1	1	½	1	1	34½
Nov. ...	½	½	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	½	½	4
	1½	1	2½	½	...	...	...	...	...	2	6	7	5	3½	3	1½	3	2	½	1½	1	½	1½	1½	45
Gen. Total.	21	16	18	12	11½	13	17	21	33½	42½	45	49½	50½	43	39	36	30½	29½	26	20½	19	20	16	16	646

TABLE IV. is the hourly totals of Tab. III. brought forward, from which Plate IV. is obtained.

WINTER QUARTER.

Wind.	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
N.	1½	2	1½	...	2	1	2½	1½	1	2½	4	4½	9	10	8	11½	8	4½	4	4½	6½	7½	6½	3½
N.N.E.	5	6½	3½	4½	3	4	4	3½	5	5½	6	9	8½	11	11½	3½	4	3	1	2	2½	4½	3½	2
N.E.	8	9½	10	4	4½	5	5	2½	5	4½	7½	10½	11	12½	10½	9½	9	11	12	12	12	9	8½	9½
E.N.E.	8½	9½	9½	13½	14	13½	10	11	8	12½	10½	4½	4½	7	5½	7	8½	7	7	8½	9½	5	4½	3
E.	7½	7	9	10½	9	7	8½	14½	26	26	29	31	30½	23	30½	27	26½	27½	23½	21	19½	21½	16	16
E.S.E.	3½	2½	4	4	4	4½	6½	4	6	17	12	8½	11	10½	10½	11	8½	4	1½	1½	1½	1	2	2½
S.E.	4½	6½	5½	4½	6	5½	5½	8½	9	12	9½	9½	14	11½	8	7½	6½	9	11½	15½	15	19½	12	8½
S.S.E.	17½	16½	14½	10½	9½	7½	8½	12	10	14	14½	21	20	20½	21½	17½	18½	15½	18	27½	26	13	20	21½
S.	19	24½	20½	22½	27	21	28½	32	35	46	55	53½	46	26	21	26	24	18½	18	12	17½	29	23½	26
S.S.W.	26	32	29½	28	25½	33½	25	18	18½	27	24	30½	53	57½	28½	35	28	40½	31	20	24	21½	32	22½
S.W.	34	34	35½	49½	51	46	51	43	46	56	65	71½	79	68½	79	62	50	37½	39½	47	32½	27	28	26
W.S.W.	23½	23½	21	24½	19½	19½	22	27	21½	19	26	16	21½	29½	29½	25	32½	31	29½	30	29½	34	29½	26½
W.	16½	13½	13½	11½	19	18	21½	14½	17½	24½	32½	46½	35½	31	27	24	18	20½	23½	22½	24	20½	11½	11½
W.N.W.	17	14	11	4	3½	5	3½	4	11½	9½	14	26	30½	27½	20	15½	8	11½	11	12	6½	15	21½	27½
N.W.	2	3½	4	4	6½	4½	4½	7½	7	3½	3½	4	3½	5½	8	7½	9½	6½	6½	4	½	1	3½	1½
N.N.W.	9	9	8	6	4½	4	3½	3½	3½	8	9	10	12½	11½	12½	12½	11	10	8	8½	12	9	6½	7½
Totals.	203	214	200½	201½	208½	199½	210	207	230½	287½	322	356½	390	363	331½	302	270½	257½	245½	248½	239	238	229	215½

SPRING QUARTER.

Wind.	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
N.	11½	9	6	8½	5½	4	7½	11	20	18½	21	22	21½	28	25½	29	25½	21	20½	26½	16	14	13	10
N.N.E.	9	10½	6½	8½	8½	14½	15½	17½	18½	25	19½	22½	27	22	24	25½	28	20½	16½	15	15½	12	15½	11½
N.E.	1	5½	4½	5½	5½	3½	2	3	10½	12½	15½	20½	19	19	21½	22	14	16½	12	6	7½	4	3	3
E.N.E.	...	...	...	...	...	½	3½	5	5	7½	10	9	14½	15½	10½	12½	9½	4	4½	2	3½	3	1½	½
E.	½	2	2	1½	1	...	½	1	2½	2½	2½	4	3	2	3½	2½	1	½	1½	2	2	...	...	1
E.S.E.	3	2	1	...	...	2	1½	1½	2	3½	4	6	4	10	3	4	2½	8	7½	5	6½	1	2	1½
S.E.	2	2	2	3½	3	...	...	4	3½	4½	11	6	6½	4½	10	3	1	2½	1	½	1	3	2	3
S.S.E.	1½	3½	2½	8½	9	7	6½	4½	9	4	5	8	9	11	5½	4	4	5½	3½	4½	4½	3	3½	3
S.	6	8½	11	4½	1½	11½	12½	15	11	15½	23½	9½	24½	19	19	14½	12	9½	6½	7½	5	1	2	3
S.S.W.	½	1	2	2½	3	3	7	12	16	19	23	23½	15	23½	29	21½	29½	29½	18½	27	17½	13	9½	10
S.W.	19½	9½	8½	8	11	14	9½	8½	11	19	21	29	33½	26	28	33½	29	9½	7½	6½	15½	14½	15½	16
W.S.W.	6	12	10	13½	7½	6	10	22½	18½	24½	27	22½	20½	23½	21½	20	22½	15½	8½	6	5½	5	4	1½
W.	3	4½	5	3½	9½	4½	3	6½	10	22½	22	17	19½	16	18	13½	11½	12	7½	6	3	2½	4	3
W.N.W.	12	14½	13½	13	12½	19½	21½	22	24½	25½	15	23½	33½	44½	45½	43½	37½	30	23½	20	15	14	14	11½
N.W.	7½	9	8	4	6½	8½	11	21	24	19½	30½	30	24	14	13½	15	16	15	10	12	16½	10½	9	8
N.N.W.	6	3½	6	4	6	5	7½	12	22	25½	25½	27½	26½	22	18	17½	11½	11½	11	8	4	8½	6½	4½
Totals.	89	97	88½	89	90	103½	119	167	208	249	276	280½	301½	300½	296	281½	255	211	160	154½	138½	109	105	91

SUMMER QUARTER.

Wind.	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
N.	...	...	...	...	...	½	½	1	½	...	...	½	½	1½	½	1	½	½	½	½	...	½	...	½
N.N.E.	½	½	...	...	½	1	½	1	...	...	...	½	1	1	½	...	1	...	...	½	...	...	...	...
N.E.	1	1	1	...	...	...	...	...	3½	3½	5½	2	1½	2½	3½	4	3½	2½	2½	2½	2	2½	½	1
E.N.E.	2½	½	½	½	1	½	½	2½	3	3	2½	4½	4½	4	5	3	2½	3	2½	2	2½	1	2	2½
E.	...	½	...	...	...	...	½	1	1	3½	3½	4½	5	4	4	6	5½	5	3	4½	3	1½	1	½
E.S.E.	3	3	2	3½	5	7	10	1½	3	5	5½	7½	7	6½	5	4	5½	5½	6	1½	3½	½	2½	3
S.E.	...	...	...	...	1	1	1½	11½	6	3½	5	5½	7	8½	9	1½	...	...	4	5	1½	2	...	...
S.S.E.	5	½	4½	6	5	6	7½	2½	16	20	18	20	11½	12½	14½	14	16	14½	19	10	5½	7½	10	7½
S.	15½	17	12	7	9½	13½	15½	25½	28½	37	34½	38½	46	52	48½	37½	34½	27	19½	18	20	23	19½	23½
S.S.W.	14	5½	8	8½	12	13½	17	18½	27½	33	48	52½	47	44½	51	40	36	25½	18½	19½	18	10½	16	6½
S.W.	12½	14½	20½	10	8	12½	18	24	26½	37	38	44	42½	38½	29½	32	30	21½	12½	7	7	10½	7½	10½
W.S.W.	3	3½	3	10½	7	7	5	9½	10	16½	19½	23	26	33	31	30	26	15½	9½	4½	1	1	4	1
W.	6	3½	3½	3	3	3½	9½	9½	12	13	14	16	14	15	17	12½	9	6½	7	5	6	3½	5	4½
W.N.W.	2	2½	4½	3	2	2½	3½	7	4½	7½	13½	11	13½	14½	16½	13½	10	7	4	1	½	1½	4½	6
N.W.	½	...	½	½	1	1½	3	4	4	5½	5½	8	7½	5	7½	7	8	4½	3	1	½	½	...	½
N.N.W.	4½	2½	1½	1½	1	4	6	5½	8	7	4½	5	6½	6	5½	4½	5	6	6½	2½	2	2	1½	2½
Totals.	70	55	60½	54	56	74	98½	124½	154	195	217½	243	241	249	248½	210½	193	144½	118	85	73	68	74	70

AUTUMN QUARTER.

Wind.	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
N.	...	...	...	...	...	...	...	...	...	1	2	4	1½	2	1½	1	2½	3½	5	2½	1½	2½	2½	...
N.N.E.	1	½	½	2½	½	...	...	½	3	5½	4½	8½	7	6	5½	5	2	2½	1½	1½	6½	2	1½	1½
N.E.	½	½	...	½	2	2	1	1	2½	2	8	7½	5½	8½	6	2½	3	4½	4½	3½	2½	½	2½	1
E.N.E.	1½	3	3½	4	5	7	9½	11½	11	16½	14½	14½	14	12	10½	13	8½	5	3½	1½	1½	2½	2½	3
E.	...	½	½	...	...	...	...	...	...	6½	6½	6	8½	8½	4½	3	3½	1	...	1	...	½	1	½
E.S.E.	2½	5½	5	8½	8	10½	4	2	8	5	6½	9	9	13	3½	11½	½	3½	2½	½	½	½	1	...
S.E.	3½	1	1	1½	1½	1	3½	1	3	6½	11½	6½	11	10	16½	11	6	6	7½	5½	4½	5	9	10
S.S.E.	13	16	16½	15	16½	10	6½	16½	19½	25½	23	20½	16½	17	24½	25½	15	14½	19	13½	11½	12	4	8
S.	12½	9½	9	9½	8	11	14	13½	16	25½	23½	33	34	39½	26½	21	40	14	13	17	15	18	16½	14
S.S.W.	21½	25	13	14½	17	17½	14	24	17½	30½	36½	37½	40½	31½	34	32½	22	31½	28½	19½	15	17½	15½	14
S.W.	12	6½	14½	14	16½	14	16	15	22	27	31½	40½	49½	46	52	50½	28½	28½	29	31½	38½	28	33	27½
W.S.W.	15½	9½	8½	12½	1½	6½	5½	7	9½	10½	19	28	25	37½	19	15½	8½	5	4	4	10	5½	13	12
W.	3½	9½	1	2½	9½	2½	2½	3½	8½	7½	9½	13½	11	12½	16	4½	4½	2	½	3	...	5	3	1½
W.N.W.	4	4½	7½	4½	3	4½	5½	7	6½	8	9½	9½	8	8	9	7	3	½	6	4½	3½	3½	2½	3
N.W.	2	4	1½	5	6	6	2½	2	3	4½	3	4	4	4	5	9½	6½	7½	6½	6½	7	7½	7	5½
N.N.W.	1½	1	2½	½	...	...	...	...	...	2	6	7	5	3½	3	1½	3	2	½	1½	1	½	1½	1½
Totals.	94½	96½	84½	95	95	92½	84½	104½	130	184	215	249½	250	259½	237	214½	157	131½	131½	117	118½	111	116	103

TABLE V. is the totals of Table IV. brought forward; these give the sum of the forces of the wind without regard to direction. From this Plate III. fig. 2 is drawn.

1837–8–9–40.

	A.M.												P.M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Winter	203	214	200½	201½	208½	199½	210	207	230	287½	322	356½	390	363	331½	302	270½	257½	245½	248½	239	238	229	215½
Spring	89	97	88½	89	90	103½	119	167	208	249	276	280½	301½	300½	296	281½	255	211	160	154½	138½	109	105	91
Summer	70	55	60½	54	56	74	98½	124½	154	195	217½	243	241	249	248½	210½	193	144½	118	85	73	68	74	70
Autumn	94½	96½	84½	95	95	92½	84½	104½	130	184	215	249½	250	259½	237	214½	157	131½	131½	117	118½	111	116	103
Mean.........	114	115⅝	108½	109⅞	112⅜	117⅜	128	150¾	180½	228¾	257⅝	282⅜	295⅝	293	278¼	252⅛	218⅞	188⅛	163¾	151¼	142¼	131½	131	119⅞

TABLE VI. is the quarterly totals of Table III. brought forward; from which Plate V. is obtained.

	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
Winter	107½	116½	202½	202	467½	142	225	395½	672	711	1158½	611	518½	329½	112	199½
Spring	395	409½	237	122	39	81½	79½	130	253½	356	403½	334	227½	549½	343	300
Summer	9½	8½	46	56	57½	106½	73½	253½	623	591	514½	300	201½	156	79	101½
Autumn	33	69½	72	179	52	120½	143½	379½	453½	570½	672	292½	137	132½	120	45
Mean.........	136¼	151	139⅜	139¾	154	112½	130⅜	289⅝	500½	557⅛	687⅛	384⅜	271⅛	291⅞	163½	161½

Report respecting the Two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, at the Expense of the British Association, from Nov. 1*st,* 1838, *to Nov.* 1*st,* 1839. *By* Sir David Brewster, K.H., F.R.S., &c.

Having selected *Inverness* and Kingussie as two suitable stations for carrying on the two series of hourly observations with the thermometer and barometer, I prevailed upon the Rev. Mr. Rutherford, of Kingussie, and Mr. Thos. Mackenzie, Teacher of Raining's School, Inverness, to undertake these observations. The necessary instruments were made by Mr. Adie, of Edinburgh, under the superintendence of Prof. Forbes, and the observations begun on the 1st of November, 1838, that month being the commencement of the meteorological year, or the *first* of the group of winter months.

While these observations were in progress, I communicated to the Association at Birmingham a specimen of those made at Kingussie, with a brief notice, which is published in the Report of last year. I have now the satisfaction of laying before the Association the observations themselves, forming two quarto volumes, a work of stupendous labour, executed, for the first time, by educated individuals, with the aid of properly instructed assistants.

The observations made at Kingussie, and, to a certain extent, those made at Inverness, contain ampler details of meteorological phænomena than any series of hourly observations with which I am acquainted. In addition to the *thermometrical* observations, the height of the *barometer* and the temperature of the mercurial column were observed every hour. The general character of the *weather* was carefully noted. The character and direction of the *wind* at every hour was recorded. The number of hours of *wind*, of *breeze*, of *calm*, of *rain*, of *snow*, and of *cloudy* and *clear* weather were regularly marked; and the number and nature of the *Auroræ Boreales* were recorded and described.

When these observations are compared with those made at *Leith*, under my superintendence, for *four* years, from 1824 to 1827 inclusive, at the expense of the Royal Society of Edinburgh,—with those made at *Plymouth*, from 1832 to 1840, at the expense of the Association, and under the able superintendence of Mr. Snow Harris,—and with those made at *Padua*, *Philadelphia*, and in *Ceylon*, we perceive very distinct traces of meteorological laws, of which no idea had been previously

formed; and I have no hesitation in stating, that when this class of observations are multiplied and extended, they will tend to general results of as great importance in pre-determining atmospherical changes, as those which have enabled the astronomer to predict the phænomena of the planetary system.

Sir David Brewster then proceeded to give a brief and *general* account of the results obtained from the observations in Inverness-shire, leaving the numerical and more minute details for the report, which will be published in a future volume of the Transactions of the Association.

In giving an account of the observations on temperature, the results obtained at Kingussie and Inverness were compared with hourly and two-hourly observations made in other places, as exhibited in the following table:

Places of Observation.		Latitude, N.	Longitude.	Height above the sea.	Distance from the sea.	Mean temp.	Time of morning mean.	Time of evening mean.	Interval between morning and evening mean.
		° ′ ″	° ′	feet.		° ′	h ′	h ′	h ′
Inverness	Observations made every hour.	57 29 34	4 12 W.	92	1 mile	45 33	8 31	7 44	11 13
Kingussie		57 4	4 5 W.	750	40 miles	42 78	8 51	7 35	10 44
Leith		55 56	3 13 W.	25	600 feet	48 36	9 13	8 27	11 15
Plymouth		50 21	4 6 W.	75	400 feet	52	8	7	11
Padua		45 36	11 55 E.	...	...	...	8 41	7 52	11 14
Philadelphia ...		39 57	75 9 W.	...	...	49 28	8 10	7 30	11 20
Colombo	Observations every 2 hours.	6 57	80 E.	36	2 miles	80 16	10 35	9 30	10 55
Kandy		7 18	80 49 E.	1682	...	74 5	10	9	11
Trincomalee ...		8 33	81 24 E.	60	...	81	10 35	8 40	11 5
					Mean of all				11 5

From this table it appears that the mean value of the critical interval is 11 hours 5 minutes, differing only 10 minutes from the result which Sir David Brewster first obtained from the hourly observations at Leith.

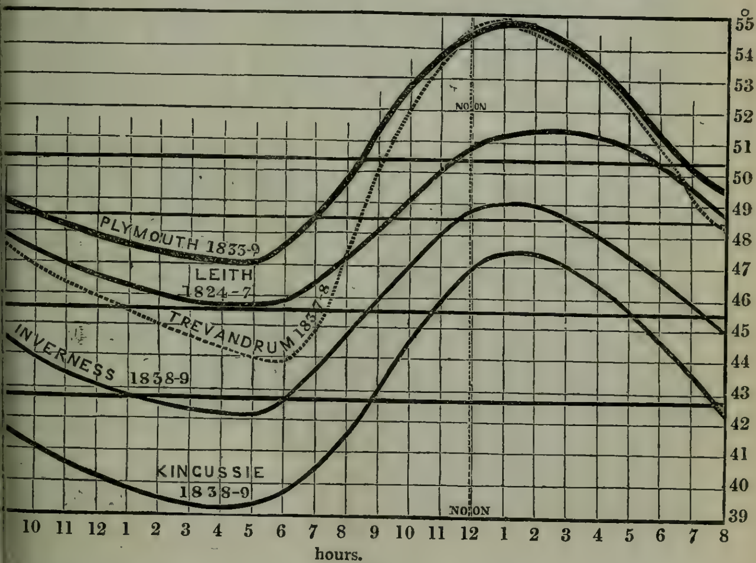
Sir David then stated to the Section, that since the Association met he had obtained from Mr. Caldecott (now present), Astronomer to His Royal Highness the Rajah of Travancore, the result of a series of hourly observations made at the Observatory of Trevandrum, situated in east longitude $5^h\ 8^m$, and

north latitude 8° 30′ 35″. These observations were made in consequence of the Rajah having seen the recommendation to establish hourly observations in the first volume of the Report of the British Association. The hours of mean temperature obtained from these valuable observations, are

Morning mean	8ʰ 34′·5
Evening mean	7 31
Critical interval	10 56·5

agreeing within 8½ minutes of the mean results given in the preceding table.

Sir David Brewster then directed the attention of the Section to the following representation of the mean annual curves of daily temperature at *Leith, Plymouth, Kingussie, Inverness,* and *Trevandrum.* He pointed out the similarity (ap-



proaching to almost entire coincidence) between the curves of Kingussie and Plymouth; an elevation of 750 feet above the sea, producing the same effect as a diminution of latitude of *six degrees.* He also drew the attention of the Section to the

curve of Trevandrum* (marked by a dotted line), in which the daily range for the annual curve greatly exceeds that of all the other curves in the diagram, a new result which no person could have anticipated.

Barometrical Observations.

Sir D. Brewster then proceeded to give a general account of the barometrical observations. The daily oscillations which they indicated correspond both in time and in magnitude with those which had been made in other parts of the world; but as the corrections had not yet been applied to all the observations, it was deemed unnecessary to make a more minute statement.

Observations on the Wind.

In comparing the number of hours of calm throughout the year, it appeared that they occurred when the temperature was lowest, and upon laying them down in a curve this curve was almost exactly the reverse of that of the mean daily temperature for the year; that is, the wind, or the commotions in the atmosphere, depends on and varies with the temperature.

"This very important and new result," Sir D. Brewster remarks, "is confirmed, in a remarkable manner, by the observations of Mr. Osler at Birmingham, made at the request and expense of the British Association, which I have seen since I arrived in Glasgow; observations of inestimable value, which exhibit more important results respecting the phænomena and laws of wind than any which have been obtained since meteorology became one of the physical sciences."

The Kingussie and Inverness observations contain many curious observations on the Aurora Borealis and other atmospherical phænomena, for an account of which we must refer to a fuller report, which will appear in a future volume of the Transactions of the British Association.

* The mean temperature is reduced 30°, so as to bring this curve among the other curves.

Report on the Fauna of Ireland: Div. Vertebrata. *Drawn up, at the request of the British Association, by* William Thompson, Esq., *(Vice-Pres. Nat. Hist. Society of Belfast,) one of the Committee appointed for that purpose.*

PART I.

It has been remarked to me, and by a distinguished naturalist, that the zoology of Ireland can hardly be worth attention, from the similarity it must bear to that of Great Britain, already so well known. But, properly considered, the zoology of an island which, in the eastern hemisphere, constitutes the most western land within the fifty-first and fifty-fifth degrees of north latitude, cannot but be highly interesting, especially in connexion with that most attractive subject, the geographical distribution of animals. In Ireland, we find within the degrees of latitude just mentioned the extreme western limits to which all our species range that are peculiar to the eastern hemisphere. In Zoology, however,—that is, in Vertebratal zoology, for of it only the present communication treats,—we do not (as some writers, without reflecting on the very different circumstances which influence the distribution of animal and vegetable life, have anticipated,) find the same interesting results as in Botany. The West and South of the island do not present us with any of the *Vertebrata* of Portugal, the western Pyrenees, or the South of Europe, which are not found elsewhere in the British Islands. The *Erica mediterranea*, *Menziesia polifolia*, *Arbutus Unedo*, &c., have no animal representatives*.

Throughout this Report it has been considered desirable to contrast the zoology of Ireland with that of Great Britain,—to present, in fact, a comparative list of the Vertebrata of the two islands. It must, however, be borne in mind, that all species found from the Channel Islands in the south, to the Shetland Islands in the north, are included in the British Fauna, and that within the degrees of latitude over which it extends, Ireland occupies but one third. Ireland is comprised within four degrees, whilst the Shetland Islands range nearly six degrees further to the north, and more than two degrees to the south the Channel Islands are situated. The Fauna of Great Britain also extends over ten degrees of longitude, whilst that of Ireland is limited to half the number.

The *physical geography* of Ireland must, like that of every

* What may be the distribution of *Lepus hibernicus* and *Mus hibernicus* is yet indeed a problem.

other country, have a primary influence on the number of *individuals* of the species which are found there either permanently or as periodical visitants. At the same time, its natural features do not differ so much from those of Great Britain as altogether to preclude the presence of more than one, or perhaps two, vertebrate animals, which have a place in the British and not in the Irish Fauna. These are the Ptarmigan (*Tetrao Lagopus*) and Alpine Hare. For the abode of the former, it does not afford a continuity of mountains of sufficient altitude and of such a nature as this bird chiefly inhabits. The haunts of the Alpine Hare (*Lepus variabilis*) are pretty similar to those of the Ptarmigan, but often at a much lower elevation.

The influence of *climate* is now to be considered; and under this head the species just mentioned might perhaps with propriety have been included. The difference between the temperature of Ireland and Great Britain cannot with any degree of certainty be said to attract to, or repel from, our island, any *species* of the British Vertebrata. Our *mild winters* in particular have otherwise great influence. The Stoat (*Mustela erminea*), for instance, very rarely in winter changes the colour of its summer fur to the warmer and more attractive garb of the Ermine, in which it is so much better known. Even in the north of the island, some species considered as birds of passage in England, except in the *extreme* south, are induced to become residents, as is the case with the Grey Wagtail (*Motacilla Boarula*), and to a very great extent with the Quail (*Perdix Coturnix*). Of the *Grallatores*, some few species remain throughout the winter in the North of Ireland, although only to the South of England are they known at this season. But, above all, the mildness of our winters is such, that some of the soft-billed birds, which are generally able to procure an abundance of food, are more disposed than in the neighbouring island to song, and accordingly at this period of the year delight us with much more of their music.

The *humidity* of our climate would seem to attract to favourite localities more Woodcocks (*Scolopax Rusticola*) than are found in any part of Great Britain, and, together with the great extent of bog throughout the island, brings hither to winter many more of the Jack Snipe (*Scolopax Gallinula*), and of the common Snipe (*Scolopax Gallinago*). The two last, above all other birds, exceed in number those found in England and Scotland. The indigenous Starlings and Snipes are as nothing compared with the numbers that pour into the island during autumn from their breeding-haunts in higher latitudes.

Our moist and rich meadows draw hither in spring more Land-Rails (*Crex pratensis*) than are generally to be found in the meadows of England and Scotland; but in the case of this bird, the far-western position of Ireland should perhaps be considered, as in Portugal the species is about equally abundant.

Mammalia.—It is so extremely difficult to procure the greater number of the animals of this class, that some, especially of the smaller species, are doubtless yet to be discovered; as known at present, they appear to fall short of those of Great Britain in an extraordinary degree. In the *Cheiroptera*, or Bats, we seem to be remarkably deficient, but time must add more species to our list. In the genus *Mus* there is a species —the *M. hibernicus*—as yet unknown elsewhere. The Squirrel (*Sciurus vulgaris*) and Dormouse (*Myoxus avellanarius*) are desiderata: of the genus *Arvicola* I have not seen an Irish example. In *Lepus*, the place of *L. timidus* and *L. variabilis* is supplied by *L. hibernicus*, as yet known only to Ireland. In *Mustela*, the Polecat (*M. Putorius*) is unknown to me; and if *M. vulgaris* be indigenous, it is much more rare than *M. erminea*, which prevails from north to south. Of *Felis Catus*, as an Irish animal, positive information is yet wanted. The *Talpa europæa* we certainly have not, though in Great Britain mole-hills may be observed close to the sea-side at some of the nearest points of land to Ireland, as at Holyhead in Wales, and Portpatrick in Scotland. The *Soreces* at present known are but two in number.

Ireland possesses as many *Birds* as from her geographical position might be anticipated. The species which appear in the catalogue of Great Britain and not in that of Ireland, are chiefly occasional visitants, many of which have no doubt extended their flight hither, although they have not come under the cognizance of the naturalist. This refers chiefly to stragglers or single birds; the species which come in flights to Great Britain generally extend their migration to Ireland also.

In the class *Reptilia* nothing particular need be remarked, except the well-known fact of the absence of Ophidian Reptiles from the island.

In *Amphibia* we have not the Toad (*Bufo vulgaris*); the Frog (*Rana temporaria*) is stated to have been introduced; the Natterjack (*Bufo Calamita*) is believed to be truly indigenous to Kerry.

The coast of Ireland offers nothing very remarkable in *Fishes*. The families having a place in the British catalogue and in which the Irish is particularly deficient, are *Percidæ*,

Sparidæ, and *Tænioideæ*. In fresh-water fishes there is, compared with England, a remarkable poverty in the species of *Cyprinidæ*; yet, leaving out of the question geological influences, there are in certain portions of Ireland lakes and rivers apparently well suited to this family. Scotland too is very deficient in the *Cyprinidæ*.

In the following catalogue of the vertebrate animals of Ireland about 420 species are included; namely, of *Mammalia*, 30?; *Aves*, 230?; *Reptilia*, 2; *Amphibia*, 4; *Pisces*, 150?; omitting in each class all extinct and naturalized species. To take a general review of the Irish *Vertebrata*, as known at present—*and every year several species are added to the catalogue*—and of the causes of the absence of species found in Great Britain, it is believed that the physical geography and climate of the island will account for that of only one or two. The want of old timber over the country might be considered an obstacle to the presence of certain Mammalia and Birds, as the *Cheiroptera*, or Bats, a large proportion of the British species of which inhabit old trees; the Squirrel, &c. In Birds, the *Picidæ*, or Woodpeckers, their congeners, and some others. The absence of all species which would not be affected by any of the above circumstances, and which we really have not, seems to me to be attributable to geographical distribution alone; thus, as the shores of continental Europe on the same parallels of latitude as Great Britain are the western boundary to many vertebrate animals unknown to that island, so again are the shores of the latter the extreme western boundary to many species unknown to Ireland*.

Note 1.—The North-east of Ireland and South-west of Scotland, although divided by so narrow a channel, are zoologically very different. The species unknown to me as Irish, but of which I have seen examples from the opposite coast, are, the Polecat (*Mustela Putorius*), Mole (*Talpa europæa*), Ciliated Shrew (*Sorex ciliatus*), the three species of Campagnol (*Arvicola amphibia*, *A. agrestis*, and *A. riparia*), and the common Hare (*Lepus timidus*)—the Black Grouse (*Tetrao Tetrix*)—the Blind-worm (*Anguis fragilis*), Adder or Viper (*Pelius Berus*), and Toad (*Bufo vulgaris*).

In the *genera* to which the animals just mentioned belong, Ireland is known to possess but one species which is not found in Scotland, the *Lepus hibernicus*, and of the terrestrial Mammalia generally, but one other, *Mus hibernicus*: of the com-

* Several species of British Birds are either not found in the West of England, or become rare towards that quarter; as the Nightingale, Nuthatch, Wryneck, Kentish Plover, Stork, &c.

mon Shrew-mouse of Ireland (*Sorex rusticus*), indeed, I have not seen any specimens from Scotland, but there can be little doubt that the animal is found there.

Note 2.—The situation of the Isle of Man—midway between Great Britain and Ireland—suggests the inquiry whether certain species not found in the latter island prevail there. On this subject Mr. E. Forbes informs me that the Mole, Squirrel, Dormouse, and Roe-deer are not indigenous to the Isle of Man; neither is the Toad, nor any species of Ophidian Reptile. A skin of the Hare of the island sent me by Mr. Forbes is that of *L. timidus*, the species found in Great Britain, and represented by *L. hibernicus* in Ireland*.

* It may be desirable, with reference to the above remarks, to allude briefly to such species as, found in Great Britain and not in Ireland, prevail further to the west. In *Mammalia*, five of the British and non-Irish species are found in the western hemisphere. They all belong to the division *Mamm. Aquatica*, and are only occasional visitants[1] to the shores of Great Britain. The species are *Calocephalus* (*Phoca*) *grœnlandicus*, *Trichecus rosmarus*, *Delphinus Tursio*, *Delphinapterus* (*Beluga*) *leucas*, *Monodon Monoceros*.

In *Aves*, sixteen British and non-Irish species prevail in the western hemisphere. Of these, the Ptarmigan (*Lagopus mutus*) only can with certainty be termed indigenous to Great Britain, and for its absence from Ireland reasons have already been assigned. *Linaria canescens* seems not yet to be properly established as an indigenous British bird. Two species, *Procellaria glacialis* and *Lobipes hyperboreus*, are periodical visitants, the former to St. Kilda only, the latter to the northern Scottish islands. The remaining twelve are occasional and very rare visitants to Great Britain or the neighbouring seas. They are *Nauclerus* (*Elanus*) *furcatus*, *Surnia funerea*, *Plectrophanes Lapponica*, *Ectopistes* (*Columba*) *migratoria*, *Macroramphus griseus*, *Tringa rufescens*, *Tringa pectoralis*, *Oidemia perspicillata*, *Clangula histrionica*, *Merganser cucullatus*, *Larus atricilla*, and *Thalassidroma Wilsoni*.

In *Reptilia*, two species which have a place in the British and not in the Irish catalogue, belong to the western hemisphere: these are *Chelonia imbricata* and *Sphargis coriacea*.

In *Amphibia*, none of the species under consideration occur in the west.

In *Pisces*, several British and non-Irish species appear in the North American list, but they are all known only as rare and occasional visitants to the shores of Great Britain. They are *Trichiurus lepturus*, *Sebastes norvegicus*, *Naucrates Ductor*, *Exocœtus exiliens*, *Engraulis encrasicholus ?*, *Echeneis Remora*, *Muræna vulgaris ?*, *Zygæna malleus*, *Scopelus Humboldtii*, and *Xiphias gladius*.

The *Mammalia*, *Reptilia*, and *Pisces* of the West are taken (with the exception of *Sphargis coriacea*) from Dr. Richardson's "Report on North American Zoology," (Report Brit. Assoc., vol. v.), and Dr. H. Storer's "Report on the Fishes &c. of Massachusetts;" *Aves*, from the Prince of Musignano's "Comparative Catalogue of the Birds of Europe and North America."

[1] Throughout this Report, the term *indigenous* is applied to species permanently resident; *periodical visitant*, to those which come annually; *occasional visitant*, to those met with at uncertain intervals.

PART II.

Div. VERTEBRATA.

Class MAMMALIA.—Sect. I. MAMM. TERRESTRIA.

Order 1.—Cheiroptera.

Fam. *Vespertilionidæ.*

[Throughout the comparative catalogue, the mark 0 denotes absence, as the mark + does presence. Thus *Vesp. Noctula* is unknown in Ireland; *V. Pipistrellus* is a British as well as an Irish species.]

Ireland.	*Great Britain.*
0	Vespertilio Noctula, *Schreb.*
0	" Leisleri, *Kuhl.*
0	" discolor, *Natt.*
Vespertilio Pipistrellus, *Geoff.*	+
0	" pygmæus, *Leach.*
0	" serotinus, *Gmel.*
0	" murinus, *L.*
0	" Bechsteinii, *Leisl.*
0	" Nattereri, *Kuhl.*
0	" emarginatus, *Geoff.*
" Daubentonii, *Leisl.*	+
0	" mystacinus, *Leisl.*
0	" ædilis, *Jenyns.*
Plecotus auritus, *Geoff.*	+
0	Plecotus brevimanus, *Jenyns.*
0	Barbastellus Daubentonii, *Bell.*
0	Rhinolophus Ferrum-equinum, *Leach.*
0	" hipposideros, *Leach.*

Of the *Vespertilionidæ*, of which 18 species are now enumerated as British, all that can be announced as Irish are the *Vesp. Pipistrellus*, *V. Daubentonii* and *Plecotus auritus*: the first and last are common from north to south of the island: of the *V. Daubentonii**, one individual was obtained by the Ordnance collectors in the county of Londonderry. That other species remain to be discovered, there is little doubt.

Of the British Bats, 4 species have each been found, but in one locality; and of 4 other species but a single individual has been procured.

Order 2.—Bestiæ.

(Feræ Insectivoræ.)

Fam. *Erinaceidæ.*

Ireland.	*Great Britain.*
Erinaceus europæus, *L.* Common throughout the island.	+

* The species determined by Mr. Jenyns.

Fam. *Talpidæ.*

Ireland.	*Great Britain.*
0	Talpa europæa, *L.*

Fam. *Soricidæ.*

Ireland.	*Great Britain.*
Sorex rusticus, *Jenyns.*	+
„ tetragonurus, *Herm.*	+
0	Sorex fodiens, *Gmel.*
0	„ ciliatus, *Sower.*
0	„ castaneus, *Jenyns.*

S. rusticus is the common Shrew of Ireland from north to south; of *S. tetragonurus* I have seen but one native specimen, which was procured by the Ordnance Survey near the Giant's Causeway.

Order 3.—FERÆ.

Fam. *Ursidæ**.

Ireland.	*Great Britain.*
Meles Taxus, *Flem.* In suitable localities throughout the island.	+

Fam. *Felidæ.*

Ireland.	*Great Britain.*
Lutra vulgaris, *Erxleb.* (?) †	+
Mustela vulgaris, *L.* (?)	+
„ erminea, *L.*	+
0	Mustela Putorius, *L.*
Martes foina, *Bell.*	+
„ Abietum, *Ray.*	+
0	Felis Catus, *L.*
Vulpes vulgaris, *Briss.*	+

The Irish Otter, named provisionally *Lutra Roensis* by Mr. Ogilby, is not now considered by that gentleman distinct from *L. vulgaris*; it is not uncommon. Of the *Mustelæ, M. Putorius* is unknown to me as Irish; and of *M. vulgaris*, which is noticed as common by Templeton and others, I have not seen a native specimen: *M. erminea* is common from north to south, and passes under the name of 'Weasel'. *Martes Abietum* is found throughout the island; of *M. foina*, but one native example (killed in the county of Antrim) is known to me. The

* *Ursus Arctos*, L. I am not aware of any written evidence tending to show that the Bear was ever indigenous to Ireland; but a tradition exists of its having been so, and it is associated with the Wolf as a native animal in the stories handed down through several generations to the present time.

† The note of interrogation *within brackets* (?) marks species doubtfully Irish.

difference of colour attributed to these animals appears to me of no value as a specific character, as in course of shedding their fur they become particoloured, the breast as well as the body presenting at the same time the colours of the Beech and the Pine Marten*. Certain data for including *Felis Catus* in the Irish catalogue are wanting: it is said to frequent the wild district of Erris (co. Mayo). *Vulpes vulgaris* is common†.

Order 4.—Glires.

Fam. *Castoridæ*.

Ireland.	*Great Britain.*
0	Arvicola amphibius, *Desm.*
0	„ arvalis, *Gm.* (agrestis, Brit. authors).
0	„ rubidus, *Baill.* (riparia, *Yarrell*).

Of the genus *Arvicola*, there is not any species known to me as indigenous to Ireland.

Fam. *Muridæ*.

Ireland.	*Great Britain.*
0	Sciurus vulgaris, *L.*
0	Myoxus avellanarius, *Desm.*
0	Mus minutus, *Pall.* (messorius, *Shaw.*)
Mus sylvaticus, *L.*	+
„ Musculus, *L.*	+
„ Rattus, *L.* (?)	+
„ hibernicus, *Thomps.*	0
„ decumanus, *Pall.*	+

Sciurus vulgaris is not now a truly native animal‡; it was introduced a few years since to the county of Wicklow, where it is said to be fast increasing in numbers. Rutty, in his Natural History of the County of Dublin, (1772,) vol. i. p. 291, remarks that it is "said to have been found in the wood in

* When the above was in the press, Mr. Eyton published in the Annals of Nat. Hist. (Dec. 1840, p. 290) some valuable remarks on the British Martens, tending to prove that they are in reality but one species. He states that the young animal has the yellow breast attributed to the Pine Marten, and the adult, the white breast of the common "species." I had also long since remarked that the yellow colour of the breast gave place to white. This view would satisfactorily explain why the yellow-breasted one—*M. Abietum*—should appear to be the more common with us, as by far the greater proportion of animals that fall victims to man are those which have not arrived at full maturity.

† *Canis Lupus*, L. Smith, in his History of Kerry (p. 173), states that Wolves were not entirely extirpated in Ireland until 1710. That noble race of domestic animals, the Irish Wolf Dog, so successfully used in their pursuit, has, since no longer required, been neglected, and must now, I fear, be called extinct.

‡ There is a tradition that the Squirrel was common in Ireland before the destruction of the native woods.

Lutterel's Town." In the same work it is observed in vol. i. p. 277, that "a vulgar error has prevailed, mentioned at Jonston's *Historia Animalium*, that the Dormouse was not found in Ireland," &c.; a sort of description of the animal follows, but by no means proving it to be a *Myoxus*. *Mus minutus* cannot be announced as Irish; but a native animal was once described to me which would agree with it; *M. sylvaticus* and *M. Musculus* are both too common over the island. The animal provisionally called *Mus hibernicus** is now so rare that I have been able to obtain for examination but one specimen, which is insufficient to establish it properly as a distinct species; *M. Rattus*, though very rare, is stated to occur occasionally in various parts of the island.

In his Natural History of Dublin, Rutty states that the *Mus decumanus* "first began to infest these parts about the year 1722." (vol. i. 281.) It has long since overspread the island.

Fam. *Leporidæ*.

Ireland.	*Great Britain.*
0	Lepus timidus, *L.*
0	,, variabilis, *Pall.*
Lepus hibernicus, *Bell.*	0
Cuniculus, *L.*	+

The only species of Hare known as Irish is the *L. hibernicus*, which is common throughout the island, as is likewise *L. Cuniculus*†.

Order 5.—PECORA‡.

Fam. *Cervidæ* §.

Ireland.	*Great Britain.*
Cervus Elaphus, *L.*	+
0	Cervus Capreolus, *L.*

* Proceedings Zool. Soc. London, 1837, p. 52.

† This animal passes under the names of *burrow* and *bush* Rabbit in the North of Ireland. These are distinguished from each other accordingly as they burrow in the ground in the ordinary manner, or live in "forms" like the Hare among bushes or underwood. This departure from their natural habit is, I conceive, only resorted to where the soil is unsuited to burrowing. In the Annals of Nat. Hist. vol. v. p. 362, a notice will be found on the subject of Hares burrowing in an exposed situation on the western coast of Ireland, to which they were introduced, and where they could not otherwise find shelter.

‡ *Bos Taurus*, L. The remains of a race of Oxen, believed to be peculiar to Ireland, are found in our bogs. The distinguishing characters are, "the convexity of the upper part of the forehead, its great proportional length, and the shortness and downward direction of the horns." See an abstract of a paper by Mr. R. Ball, "On the Remains of Oxen found in the Bogs of Ireland," in the Proceedings of the Royal Irish Academy, January 28, 1839.

§ *Cervus Dama*, L. Smith, in his History of Kerry, notices herds of Fallow Deer as frequenting the "mountains" in that county. But as these are the haunts not of this animal, but of the Stag or Red Deer (*C. Elaphus*), the latter

The *C. Elaphus*, once abundant over Ireland, is now confined to the wilder parts of Connaught, as Erris and Connemara; and to one or two localities in the South, more especially the vicinity of the lakes of Killarney.

SECT. II. MAMMALIA AQUATICA.

Order 6.—PINNIPEDA.

Fam. *Phocidæ*.

Ireland.	*Great Britain.*
Phoca vitulina, *L.*	+
0	Phoca grœnlandica, *Mull.*
0	„ barbata, *Mull.*
Halichærus Gryphus, *Bell.*	+
0	Trichecus Rosmarus, *L.*

was probably the species alluded to, especially as in the index to the volume appears "Deer, red or fallow". For a long period the Fallow Deer certainly has not been found in any part of Ireland where it could be called truly wild. A horn of this species which I possess, (through the kindness of Edward Benn, Esq., of Glenravel, county Antrim,) is stated to have been dug up from a considerable depth in a bog in his neighbourhood, but minute particulars respecting it could not be obtained. It may not be out of place to observe here, that the *C. Dama* is now well known to inhabit Greece in a wild state. Lord Derby has for some years possessed a pair of these animals of the common spotted variety, which were brought from the neighbourhood of Axium by Lord Nugent, and which, as I am informed by my friend Mr. Ogilby, who examined them attentively, during a recent visit to their noble owner, differ in no respect from the common Fallow Deer of our parks. Moreover, as remarked by the same gentleman, the universal application of the word *Dama* to this animal in the Italian, French, Spanish, and other modern languages derived from the ancient Latin, (added to the fact of the animal being still found in the forests of Italy, where there are no parks or inclosures,) points it out as the beast of chase so frequently mentioned under the same name by the Roman poets. Mr. Ogilby likewise remarks that it is in all probability the *Platycerus* of Pliny, or rather of the Greeks, from whom he copied. It is said in a note to the second edition of the *Règne Animal* to have been found in the woods of Northern Africa.

Cervus Alces, L. A horn of the true Elk (*C. Alces*), as noticed by me in the "Proceedings of the Zoological Society of London," for 1837, p. 53, was some years since presented to the Natural History Society of Belfast. To the donor it was given by a relative residing at Stewartstown, county Tyrone, who attached much value to it as a singular relic dug out of a peat-bog on his own property in that neighbourhood. That it was so obtained I am assured there cannot be a doubt. The horn is that of a very old animal, and quite perfect. On removing the paint with which it was besmeared, the horn certainly presented a fresh appearance; but might not this be attributed to the well-known preservative property of the soil in which it is said to have been found? There is not, that I am aware of, any record of this animal having ever existed in a wild state in the British Isles; but as it inhabited a wide range of latitude on the continent of Europe, it is within the bounds of probability to believe that it may have been a native species.

Sus Scrofa, L. The Wild Boar was at one period common in Ireland, but has long since become extinct. Giraldus remarks that it was of a small race, but tusks of this animal dug up in our bogs are often of goodly dimensions.

P. vitulina and *Hal. Gryphus* only, in this family, have with certainty been recognised as Irish species; they both inhabit the coasts from north to south.

Precise information is much wanted with reference to *P. barbata* as a British species; and as such, *P. grœnlandica* (or the animal so considered to be) is a recent addition to the catalogue. *Trich. Rosmarus* very rarely occurs in the Hebrides and in the Orkney and Shetland Islands.

Order 7. Cete.

Fam. *Delphinidæ*.

Ireland.	*Great Britain.*
Delphinus Delphis, *L.*	+
0	Delphinus Tursio, *Fabr.*
Phocæna communis, *Less.*	+
„ Orca, *F. Cuv.*	+
„ melas, *Bell.*	+
0	Beluga leucas, *Bell.*
Hyperoodon Butzkopf, *Lacep.*	+
0	Diodon Sowerbæi, *Jard.*
0	Monodon Monoceros, *L.*

D. Delphis, *P. communis* and *P. Orca* are considered to prevail on various parts of the coast of Ireland, the second to be the most common, the last the rarest; of all, I have seen native specimens, but cannot from personal knowledge speak of the comparative abundance or scarcity of the species. *P. melas* has been observed on the western and southern coasts; *Hyp. Butzkopf* along the eastern coast. The four *Delphinidæ* which cannot be enumerated in the Irish catalogue are very rare as British species; of *Diodon Sowerbæi* a single specimen only is on record.

Fam. *Balænidæ*.

Ireland.	*Great Britain.*
Physeter macrocephalus, *L.*	+
„ Tursio, *L.*	+
Balæna Mysticetus, *L.*	+
Balænoptera Boops, *Flem.*	+

According to Dr. Molyneux*, the "Spermaceti Whale" has been captured on the north and north-west coasts. Smith notices one, taken near Youghal; and Rutty, in his Natural History of Dublin, mentions an individual as cast ashore in 1766. Templeton states that *Phys. Tursio* is of occasional occurrence in the West. *Bal. Mysticetus* has been rarely captured on various parts of the coast. Of a *Balænoptera* (*Balæna rostrata*) which was taken on the western coast some years ago a very full account has been published by Dr. Jacob in the Dublin Philosophical Journal.

* Phil. Trans., vol. xix. 1795–6, p. 508.

PART III.

Class AVES.

Order 1.—Raptores.

Fam. *Vulturidæ.*

Ireland.	*Great Britain.*
0	Neophron Percnopterus, *Sav.*

This bird has a place in the British Fauna from its occurrence in England on one or two occasions. Africa is its head quarters.

Fam. *Falconidæ.*

Ireland.	*Great Britain.*
Aquila Chrysaëtos, *Vig.*	+
Haliæetus albicilla, *Selby.*	+
Pandion Haliæetus, *Sav.*	+
Astur palumbarius, *Bechst.* (?)	+
Accipiter fringillarius, *Ray.*	+
Falco grœnlandicus, *L. Hancock.*	+
,, Islandicus, *Lath. Hancock.* (?)	+
,, peregrinus, *L.*	+
,, Subbuteo, *L.*	+
,, rufipes, *Bechst.*	+
,, Tinnunculus, *L.*	+
,, Æsalon, *Gmel.*	+
Buteo vulgaris, *Bechst.*	+
,, Lagopus, *Vig.*	+
Pernis apivorus, *Cuv.*	+
Circus rufus, *Briss.*	+
,, cyaneus, *Flem.*	+
0	Circus cineraceus, *Shaw.*
Milvus Ictinus, *Sav.*	+
0	Elanus furcatus, *Sav.*

The two first-named species, the Golden and Sea Eagles are in Ireland, as in Scotland, more numerous than in England. *Pandion Haliæetus* is chiefly confined to the more southern half of the island. *Astur palumbarius* has a place not only in the older county histories, but in Mr. Templeton's catalogue; I have not myself seen any specimen which could be verified as native. *Accipiter fringillarius, Falco peregrinus, F. Tinnunculus, F. Æsalon, Buteo vulgaris, Circus rufus,* and *C. cyaneus,* inhabit suitable localities throughout Ireland: in the wild and mountainous parts of the country which are destitute of wood, *B. vulgaris* makes the precipitous rocks its habitation. *Falco grœn-*

landicus as distinguished by Mr. Hancock from *F. Islandicus**, has in one instance been obtained in Donegal†: under the latter name Mr. Templeton records a specimen, killed in the county of Antrim, but as both these terms were then used synonymously, it must remain doubtful whether it was this or the former species. By this naturalist the *F. Subbuteo* was on two occasions observed in Ireland. *Falco rufipes* has once been obtained, in the neighbourhood of Dublin. *Buteo Lagopus* is a very rare winter, as *Pernis apivorus* is a summer, visitant. Smith, in his History of Cork, (completed in 1749,) remarks of the *Milvus Ictinus*, "These birds are so common that they need no particular description; . . . . . . with us it remains all the year‡." At present the species is unknown in that county. The terms Kite and Goshawk being applied indiscriminately in Ireland to the Buzzards, and the latter sometimes to the Peregrine Falcon, renders it somewhat dubious whether the proper names have always been legitimately employed in the county histories, &c. The *Milvus Ictinus* has, on what was considered sufficient authority, been noticed as an extremely rare visitant to the North §.

Of our desiderata, the *Circus cineraceus* is a species, which from its general resemblance to *C. cyaneus*, might readily be overlooked; it will probably yet be added to the Irish catalogue. *Elanus furcatus*, an American species, has only twice been taken in Great Britain.

Fam. *Strigidæ*.

Ireland.	*Great Britain.*
Bubo maximus, *Sibbald.*	+
Otus vulgaris, *Flem.*	+
„ Brachyotos, *Cuv.*	+
Scops Aldrovandi, *Will. & Ray.*	+
Surnia nyctea, *Dum.*	+
0	Surnia funerea, *Dum.*
Strix flammea, *L.*	+
Ulula stridula, *Selby.*	+
0	Noctua Tengmalmi, *Selby.*
0	„ passerina, *Selby.*

Of the occurrence of either *Bubo maximus* or *Scops Aldrovandi* in Ireland, there is but a single record. *Otus vulgaris*

* Annals of Natural History, vol. ii. p. 249.

† The description of this individual, supplied me, previous to the appearance of Mr. Hancock's paper, by John Vandeleur Stewart, Esq., of Rockhill, Letterkenny, in whose collection it is, is so ample, as to prove its species beyond any doubt.

‡ Vol. ii. p. 326, 2nd edit.

§ Ann. Nat. Hist., vol. i. p. 156.

and *Strix flammea* are common and resident. *Otus Brachyotos* is a regular winter resident; at the same season *Surnia nyctea* has occasionally been met with. *Ulula stridula* is included in the older county histories; on what was considered sufficient authority it was noticed as an Irish species in Annals of Natural History, vol. i. p. 156.

Surnia funerea has its place in the British catalogue from a single individual having been taken off the coast of Cornwall. *Noctua Tengmalmi* and *N. passerina* have been very rarely met with in England.

Order 2.—Insessores.

Div. 1.—Dentirostres.

Fam. *Laniadæ.*

Ireland.	*Great Britain.*
Lanius Excubitor, *L.*	+
0	Lanius Collurio, *L.*
0	,, rufus, *L.*

The *L. Excubitor* only in this family can be announced as Irish: its occurrence in a number of instances is on record.

L. Collurio is a regular summer visitant to England; *L. rufus* but a very rare and occasional one.

Fam. *Muscicapidæ.*

Ireland.	*Great Britain.*
Muscicapa grisola, *L.*	+
0	Muscicapa luctuosa, *Temm.*

M. grisola is a regular summer visitant to Ireland.

M. luctuosa is in England considered only as an occasional visitant (Selby).

Fam. *Merulidæ.*

Ireland.	*Great Britain.*
Cinclus aquaticus, *Bechst.*	+
Merula viscivora, *Selby.*	+
,, pilaris, *Selby.*	+
,, musica, *Selby.*	+
,, iliaca, *Selby.*	+
,, vulgaris, *Ray.*	+
,, torquata, *Selby.*	+
0	Merula Whitei, *Jard.*
Oriolus Galbula, *L.*	+

Cinclus aquaticus, *Mer. musica* and *M. vulgaris* are common and resident; so likewise is *M. viscivora,* but not to the same extent, although its increase in Ireland of late years has

fully kept pace with that in Great Britain: so mild have been our few last winters, that the song of *M. musica* was almost daily heard. *Mer. pilaris* and *M. iliaca* regularly take up their abode with us in winter, as does *M. torquata* in summer. *Oriolus Galbula* has in a few instances been met with in various parts of Ireland, and as far north as Donaghadee, co. Down.

Mer. Whitei has on two occasions occurred in England.

Fam. *Sylviadæ.*

Ireland.	*Great Britain.*
Accentor modularis, *Cuv.*	+
0	Accentor alpinus, *Bechst.*
Erythaca Rubecula, *Swains.*	+
Phœnicura Ruticilla, *Swains.*	+
,, Tithys, *Jard. & Selby.*	+
0	Phœnicura Suecica, *Selby.*
Saxicola Œnanthe, *Bechst.*	+
,, Rubetra, *Bechst.*	+
,, Rubicola, *Bechst.*	+
Salicaria Locustella, *Selby.*	+
,, Phragmitis, *Selby.*	+
,, arundinacea, *Selby.*	+
0	Philomela Luscinia, *Swains.*
Curruca Atricapilla, *Bechst.*	+
,, hortensis, *Bechst.*	+
,, cinerea, *Bechst.*	+
0	Curruca Garrula, *Briss.*
0	Melizophilus provincialis, *Leach.*
Sylvia Hippolais, *Lath.*	+
,, Sibilatrix, *Bechst.* (?)	+
,, Trochilus, *Lath.*	+
Regulus Aurocapillus, *Selby.*	+
0	Regulus ignicapillus, *Jenyns.*
Parus major, *L.*	+
,, cœruleus, *L.*	+
,, palustris, *L.*	+
,, ater, *L.*	+
,, caudatus, *L.*	+
0	Parus cristatus, *L.*
Calamophilus biarmicus, *Leach.*	+
Motacilla Yarrellii, *Gould.* (*M. alba*, preceding British authors).	+
Motacilla Boarula, *L.*	+
,, flava, *Ray.*	+
0	Motacilla neglecta, *Gould.*
Anthus obscurus, *Temm.** (Rock Pipit, Brit. authors).	+
Anthus pratensis, *Bechst.*	+
,, arboreus, *Bechst.* (?)	+
0	Anthus Richardi, *Vieill.*

* Not *A. aquaticus*, Bechst. See Temm. Man., part iv. p. 929.

Accentor modularis, Erythaca Rubecula, Saxicola Rubicola, Regulus Aurocapillus, Parus major, P. cæruleus, P. ater, Motacilla Yarrellii, M. Boarula, Anthus obscurus, A. pratensis are common and resident: in the wilder districts, especially towards the west, *M. Boarula* is rare. *Parus caudatus* and *P. palustris* are likewise resident, but much less common than the preceding species; the former is increasing with the spread of plantations; the latter is very little known as an Irish bird. *Phœnicura Ruticilla* is but of occasional and rare occurrence; *Ph. Tithys* can only be announced with certainty as having once been met with. *Saxicola Œnanthe, S. Rubetra, Salicaria Phragmitis, Curruca cinerea, Sylvia Trochilus* are the most common and widely dispersed of the regular summer visitants; *Salicaria Locustella* should perhaps be included with them, but its retired habits render it less known. *Salicaria arundinacea* is recorded by Templeton as once seen by him near Belfast, and in a single instance *Calamophilus biarmicus* has been obtained on the banks of the Shannon. *Curruca Atricapilla* is probably a regular summer visitant to select localities, and has in several instances been known to winter in Ireland. *C. hortensis* is with certainty known only as an occasional summer visitant. *Sylvia Hippolais* and *Motacilla flava* appear every summer in comparatively few localities over the island. *Sylvia Sibilatrix* and *Anthus arboreus* are believed to visit Ireland in summer, but it yet remains to be determined.

Of our desiderata, *Accentor alpinus, Phœnicura suecica, Regulus Ignicapillus,* and *Anthus Richardi* are only known as rare and occasional visitants to England. *Motacilla neglecta* cannot without further information be regarded otherwise than a species of occasional occurrence in Great Britain. There is little hope of *Parus cristatus* being found in Ireland: it is, as a British bird, known only in Scotland, where it especially frequents the pine forests. *Melizophilus provincialis* has been met with only in the more southern half of England. Of *Philomela Luscinia* and *Curruca Garrula*, the former is unknown in the West of that country, and the latter would seem to become rare towards the same quarter. With increased attention, more species in this family will doubtless be added to the Irish catalogue.

Fam. *Ampelidæ*.

Ireland.	*Great Britain.*
Bombycilla garrula, *Bonap.*	+

An occasional winter visitant to Ireland.

Order Insessores.

Div. 2.—Conirostres.

Fam. *Fringillidæ.*

Ireland.	*Great Britain.*
0	Alauda alpestris, *L.*
Alauda arvensis, *L.*	+
„ arborea, *L.*	+
0	Plectrophanes Lapponica, *Selby.*
Plectrophanes nivalis, *Meyer.*	+
Emberiza Miliaria, *L.*	+
„ Schœniculus, *L.*	+
„ Citrinella, *L.*	+
0	Emberiza Cirlus, *L.*
0	„ hortulana, *L.*
Fringilla Cœlebs, *L.*	+
„ Montifringilla, *L.*	+
Passer domesticus, *Ray.*	+
0	Passer montanus, *Ray.*
Coccothraustes vulgaris, *Flem.* (Fring. Coccothraustes, *Temm.*)	+
Coccothraustes Chloris, *Flem.*	+
Carduelis elegans, *Steph.*	+
„ Spinus, *Steph.*	+
Linaria minor, *Ray.*	+
„ cannabina, *Sw.*	+
„ montana, *Ray.*	+
0	Linaria canescens, *Gould.*
Pyrrhula vulgaris, *Temm.*	+
„ Enucleator, *Tem.* (?)	+
Loxia curvirostra, *L.*	+
0	Loxia Pytiopsittacus, *Bechst.*
„ leucoptera, *Gmel.*	+

Alauda arvensis, Emb. miliaria, E. Schœniculus and *E. Citrinella, Fring. Cœlebs, Pass. domesticus, Cocc. Chloris, Linaria minor* and *L. cannabina* are common and resident. *Alauda arborea, Card. elegans, Lin. montana* and *Pyrr. vulgaris* are likewise resident, but more local than the others. *Plect. nivalis* is a regular winter visitant to the North of Ireland, but little known in the South; *Fring. Montifringilla* is a frequent, perhaps a regular visitant at the same period. *Cocc. vulgaris, Card. Spinus*, and *Loxia curvirostra* occasionally visit us in winter, the first-mentioned being the most rare, and occurring in the fewest numbers; the last-named has in some instances bred in Ireland. *Pyrr. Enucleator* would seem from a note of Mr. Templeton's to have been once met with near Belfast. *Loxia leucoptera* has been obtained on one occasion.

Alauda alpestris, *Plect. Lapponica*, *Emb. hortulana* and *Loxia Pytiopsittacus** are very rare and occasional visitants to Great Britain. *Emberiza Cirlus* and *Passer montanus* are local species in England, the former visiting only a portion of the South. *Linaria canescens* I have not yet sought to distinguish from its allies.

Fam. *Sturnidæ*.

Ireland.	*Great Britain.*
Sturnus vulgaris, *L.*	+
Pastor roseus, *Temm.*	+

The former species is somewhat local and partially resident; it abounds in particular localities during winter. The latter is a rare summer visitant, but has been met with in all quarters of the island.

Fam. *Corvidæ*.

Ireland.	*Great Britain.*
Fregilus Graculus, *Selb.*	+
Corvus Corax, *L.*	+
„ Corone, *L.*	+
„ Cornix, *L.*	+
„ Frugilegus, *L.*	+
„ Monedula, *L.*	+
Pica melanoleuca, *Vieill.*	+
Garrulus glandarius, *Flem.*	+
0	Nucifraga Caryocatactes, *Briss.*

Freg. Graculus is pretty generally diffused over the marine cliffs of Ireland, and rarely inhabits inland localities. All the species of *Corvus* are resident and common; *C. Corone* least so. Of *Pica melanoleuca* it is stated by Smith, in his History of Cork, (1749,) that it "was not known in Ireland seventy years ago, but is now very common†. Rutty, in his Natural History of Dublin, observes respecting this bird, "It is a foreigner, naturalised here since the latter end of King James the Second's reign, and is said to have been driven hither by a strong wind."‡ *Garr. glandarius* inhabits only some parts of the island, especially towards the centre and south.

Nucif. Caryocatactes is but a rare visitant to Great Britain. I have heard that it once occurred at Silvermines, co. Tipperary.

* It is more than probable that some of the later British specimens noticed as this bird were merely *L. curvirostra*, with the point of the lower mandible not extending beyond the profile of the upper.

† Vol. ii. p. 330. ‡ Vol. i. p. 308.

Order Insessores.

Div. 3.—Scansores.

Fam. *Picidæ.*

Ireland.	*Great Britain.*
0	Picus viridis, *L.*
Picus major, *L.*	+
0	,, minor, *L.*
0	,, martius, *L.*
0	Yunx Torquilla, *L.*

Owing to the general scarcity of wood, especially old, this family of birds is rare. *P. major* only can with certainty be introduced to our catalogue, and it is but a very rare visitant. "*Picus varius minor*, Lesser Spotted Woodpecker," is given as one of the birds of the co. Dublin by Rutty*. In Dr. Patrick Brown's catalogue of the Birds of Ireland it likewise has a place, but was probably copied from Rutty. In Smith's Waterford† appears "*Picus Martis*, the Woodpecker, a bird rare in this county:" the *P. martius* can hardly have been here meant.

Picus viridis would appear to be generally distributed in suitable localities in Great Britain, and *P. minor* to be so in England; *P. martius* is a very rare visitant. *Yunx Torquilla*, one of the summer birds of passage to England, decreases in numbers towards the west of that country.

Fam. *Certhiadæ.*

Ireland.	*Great Britain.*
Certhia familiaris, *L.*	+
Troglodytes europæus, *Cuv.*	+
Upupa Epops, *L.*	+
0	Sitta europæa, *L.*

Cert. familiaris constantly inhabits the best-wooded districts throughout Ireland; *Trog. europæus* is common and resident. *Upupa Epops* is a rare visitant but has been taken in all quarters of the island.

Sitta europæa is somewhat local in England, and towards the West is said to become more rare.

Fam. *Cuculidæ.*

Ireland.	*Great Britain.*
Cuculus canorus, *L.*	+
Coccyzus americanus, *Bonap.*	+

The former is a regular vernal migrant to Ireland, and is generally diffused; the latter has on two or three occasions been obtained in the counties of Cork and Dublin.

* Vol. i. p. 302. † P. 338.

Order Insessores.

Div. 4.—Fissirostres.

Fam. *Meropidæ*.

Ireland.	*Great Britain.*
Coracias garrula, *L.*	+
Merops Apiaster, *L.*	+

Both species are extremely rare and known only to have occurred on two or three occasions in Ireland.

Fam. *Halcyonidæ*.

Ireland.	*Great Britain.*
Alcedo Ispida, *L.*	+

Is diffused over suitable localities and resident.

Fam. *Hirundinidæ*.

Ireland.	*Great Britain.*
Hirundo rustica, *L.*	+
,, urbica, *L.*	+
,, riparia, *L.*	+
Cypselus Apus, *Flem.*	+
,, alpinus, *Temm.*	+

The three species of *Hirundo* and *Cyp. Apus* are regular vernal migrants to Ireland. *Cyp. alpinus* has been obtained once off Cape Clear, and again in the county of Dublin.

Fam. *Caprimulgidæ*.

Ireland.	*Great Britain.*
Caprimulgus europæus, *L.*	+

A regular summer visitant to certain portions of the island both north and south, but very local.

Order 3.—Rasores.

Fam. *Columbidæ*.

Ireland.	*Great Britain.*
Columba Palumbus, *L.*	+
0	Columba Œnas, *L.*
,, Livia, *Briss.*	+
,, Turtur, *L.*	+
0	,, migratoria, *L.*

C. Palumbus and *C. Livia* are common and resident in their very different places of abode. *C. Turtur* is an occasional summer visitant.

C. Œnas is very partially distributed in England, being chiefly confined to the midland and eastern counties. Of *C. migratoria* a single specimen, supposed to have been in a wild state, has been obtained in Great Britain*.

* *Phasianus Colchicus*, and its var. β the Ring-necked, are common in many parts of Ireland to which they have been introduced.

Fam. *Tetraonidæ.*

Ireland.	*Great Britain.*
0	Tetrao Tetrix, *L.*
Lagopus scoticus, *Selby.*	+
0	Lagopus mutus, *Leach.*
Perdix cinerea, *Lath.*	+
„ Coturnix, *Lath.*	+

In the genera *Tetrao* and *Lagopus*, which in the eye of the sportsman if not of the naturalist are of all others the most attractive, we now possess but one species, the *Lagopus scoticus*. This is common to heathy tracts, from the low-lying bog to the mountain top throughout Ireland, and is in many places as abundant as in the highlands of Scotland. Of the *Tetrao Urogallus*, Smith, in his History of Cork*, observes, that it is now found rarely in Ireland since our woods have been destroyed. In his Natural History of Dublin, Rutty remarks, that "one of these [*T. Urogallus*] was seen in the county of Leitrim about the year 1710, but they have entirely disappeared of late, by reason of the destruction of our woods†." In the work above cited, Smith describes the *T. Tetrix* as "frequent." Mr. Templeton states that he had been informed by excellent authority, that "black game is mentioned in some of the old leases of the county of Down"‡; and elsewhere this bird is noticed as a native. That the species alluded to by Smith was the *T. Tetrix* would seem hardly to admit of doubt, as in addition to it he enumerates the Red Grouse. If it were really indigenous, its extinction must, I conceive, be attributed to the destruction of our native woods. The *Lagopus mutus* is not now, nor do I conceive ever was, indigenous to this island. There seems not to be in any part of Ireland a continuity of mountains of sufficient altitude to be suited to the Ptarmigan's abode. *Perdix cinerea* is common and resident. *P. Coturnix* frequents the most highly-cultivated districts in summer, and within the last few years has in certain localities remained throughout the winter.

Fam. *Struthionidæ.*

Ireland.	*Great Britain.*
0	Otis Tarda, *L.*
Otis Tetrax, *L.*	+

The latter species, which is a very rare visitant to Great Britain, has once been obtained in Ireland, in the county of Wicklow a few years ago. *O. Tarda* is enumerated by Smith

* 1749. † Vol. i. p. 302.
‡ Magazine of Natural History, vol. i. new series.

as one of the birds of the county of Cork; it is long since extinct.

Order 4.—Grallatores.

Fam. *Charadriadæ.*

Ireland.	*Great Britain.*
0	Cursorius Isabellinus, *Meyer.*
Œdicnemus crepitans, *Temm.*	+
Charadrius pluvialis, *L.*	+
„ Morinellus, *L.*	+
„ Hiaticula, *L.*	+
0	Charadrius minor, *Meyer.*
0	„ Cantiacus, *Lath.*
Squatarola cinerea, *Cuv.*	+
Vanellus cristatus, *Meyer.*	+
Strepsilas Interpres, *Leach.*	+
Arenaria Calidris, *Meyer.*	+
Hæmatopus Ostralegus, *L.*	+

In this family, *Van. cristatus* and *Hæm. Ostralegus* are common and resident. *Char. pluvialis* and *C. Hiaticula* are common and partially resident; the numbers of both species (certainly of the former) being much increased by an autumnal migration from higher latitudes. *Squat. cinerea, Strep. Interpres,* and *Aren. Calidris,* are regular periodical visitants. *Œdic. crepitans* and *Char. Morinellus* very rarely visit Ireland.

Of the *Cursorius Isabellinus,* four individuals have been obtained in England and Wales. *Char. minor* has a place in the British catalogue from a single specimen killed in Sussex. To the east and south-east of England only, I believe, is *Char. Cantianus* known.

Fam. *Gruidæ.*

Ireland.	*Great Britain.*
0	Grus cinerea, *Bechst.*

In his History of Cork, Smith states that "this bird was seen in this country during the remarkable frost of 1739."

Fam. *Ardeidæ.*

Ireland.	*Great Britain.*
Ardea cinerea, *Lath.*	+
„ purpurea, *L.*	+
0	Ardea alba, *L.*
„ Garzetta, *L.*	+
0	„ russata, *Wagler.*
0	„ Ralloides, *Scop.*
Botaurus stellaris, *Steph.*	+
0	Botaurus Mokoho, *Vieill.*
„ minutus, *Selby.*	+
Nycticorax europæus, *Steph.*	+

Ireland.	Great Britain.
0	Ciconia alba, *Ray.*
0	,, nigra, *Ray.*
Platalea Leucorodia, *L.*	+
Ibis Falcinellus, *Temm.*	+

In this family, the *Ardea cinerea* only is common and resident; *Botaurus stellaris* is, in consequence of the improvement of the bogs, becoming gradually scarcer, and, as a resident species, is confined to few localities. *Bot. minutus, Nyct. europæus, Plat. Leucorodia, Ibis Falcinellus,* are rare visitants. *Ardea purpurea* and *A. Garzetta* have each been once obtained; of the latter species, one or two other examples in addition to that alluded to*, are said to have occurred on the southern coast.

The six British species of the *Ardeidæ* which are desiderata in Ireland, are, with the exception of *Ciconia alba*, very rare visitants; three of them, indeed, are with certainty placed in the catalogue from their occurrence each in a single instance.

Fam. *Scolopacidæ.*

Ireland.	Great Britain.
Numenius arquata, *Lath.*	+
,, Phæopus, *Lath.*	+
Totanus fuscus, *Leisl.*	+
,, Calidris, *Bechst.*	+
,, Ochropus, *Temm.*	+
,, Glareola, *Temm.* (?)	+
,, Hypoleucos, *Temm.*	+
,, Glottis, *Bechst.*	+
Recurvirostra Avocetta, *L.*	+
Himantopus melanopterus, *Temm.*	+
Limosa melanura, *Leisl.*	+
,, rufa, *Briss.*	+
Scolopax Rusticola, *L.*	+
,, Sabini, *Vigors.*	+
,, major, *Gmel.* (?)	+
,, Gallinago, *L.*	+
,, Gallinula, *L.*	+
0	Macroramphus griseus, *Leach.*
Machetes pugnax, *Cuv.*	+
Tringa subarquata, *Temm.*	+
,, variabilis, *Meyer.*	+
0	Tringa pectoralis, *Bonap.*
" maritima, *Brunn.*	+
0	,, Temminckii, *Leisl.*
,, minuta, *Leisl.*	+
,, Canutus, *L.*	+
0	,, rufescens, *Vieill.*
0	Lobipes hyperboreus, *Steph.*
Phalaropus lobatus, *Flem.*	+

* See Templeton in Magazine of Natural History, vol. i. new series.

The word "resident," in the sense in which it has hitherto been used, will not apply to any of the *Sclopacidæ*. The species of which a portion breed in Ireland, and are common at all seasons, are *Num. arquata*, *Tot. Calidris*, *Scol. Gallinago*, and *Trin. variabilis*. *Tot. Hypoleucos* is a regular summer visitant; at the same season *T. Ochropus* has occasionally been met with, and very rarely *T. Glareola**? The regular autumnal migrants are *Num. Phæopus*, *Tot. Glottis*, *Lim. rufa*, *Machetes pugnax*, *Trin. subarquata*†, *T. minuta*†, *T. Canutus*; and to these probably *Lim. melanura* might with propriety be added. In the North of Ireland these species are met with for a longer or shorter period during autumn, and generally move southward on the approach of winter: to this there are, however, occasional exceptions, in some remaining behind; to *T. Canutus* and *T. Glottis* this more especially applies. *Num. Phæopus* is, in consequence of being in large flocks, much better known upon our coasts in spring when migrating northwards, than in the autumn, when it appears only in small numbers. *Scol. Rusticola* and *S. Gallinula* come from more northern latitudes to abide the winter; the former has of late years bred in various parts of Ireland‡. *Scol. Sabini*, *Trin. maritima*, and *Phal. lobatus*, have on several occasions been obtained; *T. maritima* is probably a regular winter visitant. *Recur. Avocetta* and *Him. melanopterus* have twice been noticed. *Tot. fuscus* is on record, from a single example having occurred: this species may have escaped notice from its general similarity to the common *Tot. Calidris*. *Scol. major* should not perhaps be included even with a mark of doubt, as I have not seen any example of it, killed in Ireland, but sportsmen have described birds to me that can hardly be any other, and have correctly remarked on the peculiarity of habits in which they differed from the *Scol. Gallinago*.

Of our desiderata in the *Scolopacidæ*, *Tr. pectoralis* has once, and *Tr. rufescens* twice, been obtained in England; *Macr. griseus* is a "very rare," and *Tr. Temminckii* an "occasional visitant" to that country. *Lobipes hyperboreus* is in Great Britain chiefly confined to the more northern isles and coasts of Scotland.

Fam. *Rallidæ*.

Ireland.	*Great Britain.*
0	Glareola Pratincola, *Leach.*
Rallus aquaticus, *L.*	+

* See Annals of Natural History, vol. v. p. 8.

† Ibid., vol. iv. p. 285.

‡ Annals of Natural History, vol. ii.

Ireland.	*Great Britain.*
Crex pratensis, *Bechst.*	+
„ Porzana, *Selby.*	+
0	Crex Baillonii, *Selby.*
0	„ pusilla, *Selby.*
Gallinula Chloropus, *Lath.*	+
Fulica atra, *L.*	+

R. aquaticus and the two last are resident and common, as the species ordinarily are in other countries. *Crex pratensis* is a regular summer visitant, and abundant; *C. Porzana* a species of occasional occurrence at the same season.

Of *Glareola Pratincola*, four individuals are on record as British. *Crex Baillonii* and *C. pusilla* are very rare visitants to England.

Order 5.—Natatores.

Fam. *Anatidæ.*

Sub-Fam. *Anserinæ.*

Ireland.	*Great Britain.*
Anser palustris, *Flem.*	+
„ ferus, *Flem.*	+
„ Erythropus, *Flem.*	+
„ Bernicla, *Flem.*	+
„ Brenta, *Flem.*	+
0	Anser ruficollis, *Pall.*
0	Plectopterus Gambensis, *Steph.*
Cygnus ferus, *Ray.*	+
„ Bewickii, *Yarr.*	+

A. ferus (*A. Segetum*, Steph.), *A. Erythropus* (*A. albifrons*, Steph.), *A. Bernicla* and *A. Brenta* are regular winter visitants to Ireland, the two last, but more especially *A. Brenta*, being in great numbers in their very different places of abode. *A. palustris* (*A. ferus*, Steph.) is much more rare than the two first mentioned: at one period it bred in this country, but has long since ceased to do so.

Wild Swans are seen every winter in some parts of Ireland, but it cannot be positively stated of either *C. ferus* or *C. Bewickii*, that it is a regular winter visitant; that one or both may be so considered is a fair inference, from the same lakes being annually visited by " wild Swans." Of both species I have seen examples, which were obtained in the north, east, and west of the island; *C. Bewickii* is of much more frequent occurrence than *C. ferus*. The Egyptian Goose (*Anser ægyptiacus*) and Canada Goose (*Anser Canadensis*) have at different times been shot on the Irish coast: the former species had doubtless escaped from ponds; the latter, too, had in all probability done so.

A. ruficollis is a very rare visitant to England. *A. Gambensis* has been but once obtained, and whether the individual so recorded was a wild bird is very questionable, as the species does not appear to have been met with on the European continent.

Fam. *Anatidæ.*

Sub-Fam. *Anatinæ.*

Ireland.	*Great Britain.*
Tadorna Vulpanser, *Flem.*	+
0	Tadorna rutila, *Steph.*
Spathulea clypeata, *Flem.*	+
Chauliodus Strepera, *Sw.*	+
Anas Boschas, *L.*	+
Querquedula acuta, *Selby.*	+
,, Crecca, *Steph.*	+
,, Circia, *Steph.*	+
0	Querquedula glocitans, *Vigors.*
Mareca Penelope, *Selby.*	+

Three species, *T. Vulpanser*, *A. Boschas*, and *Q. Crecca*, may be called resident from their breeding in Ireland and being met with at all seasons; but of the numbers of the two last which are here in winter, but a small proportion is bred in the country. *Spat. clypeata* is most probably indigenous, as in England. It has occurred in Ireland in May, and I once obtained an adult female, shot in July. *Querq. acuta* and *Mar. Penelope* are regular winter visitants. *Chaul. Strepera* and *Querq. Circia* (*A. Querquedula*) are of rare occurrence at the same season; of the latter I have not myself seen a duly-authenticated Irish example; it is noticed in Tighe's Kilkenny, and in a catalogue of the Birds of Dublin supplied me by Mr. R. Ball.

Tad. rutila and *Querq. glocitans* are extremely rare visitants to England.

Fam. *Anatidæ.*

Sub-Fam. *Fuligulinæ.*

Ireland.	*Great Britain.*
Somateria mollissima, *Leach.*	+
,, spectabilis, *Leach.*	+
Oidemia fusca, *Flem.*	+
,, nigra, *Flem.*	+
0	Fuligula rufina, *Steph.*
Fuligula ferina, *Steph.*	+
0	,, Nyroca, *Steph.*
0	,, dispar, *Steph.*
,, Marila, *Steph.*	+
,, cristata, *Steph.*	+
Clangula vulgaris, *Leach.*	+
0	Clangula histrionica, *Steph.*
Harelda glacialis, *Steph.*	+

The three species of *Fuligula* noticed as Irish, and *Clang. vulgaris,* are regular winter visitants: *Oid. nigra* and *Har. glacialis* would likewise seem to be so, but in very small numbers; for four winters successively I have obtained a single specimen of the last in Belfast Bay. *Oid. fusca, Som. mollissima,* and *S. spectabilis,* can only be noticed as very rare visitants; once only has the last been obtained*.

Ful. rufina has in a very few instances occurred in England. *F. Nyroca* is but a rare and occasional visitant; and *F. dispar* has once been procured. *Clang. histrionica* is likewise very rare.

Fam. *Anatidæ.*

Sub-Fam. *Merganinæ.*

Ireland.	*Great Britain.*
Mergus Merganser, *L.*	+
„ Serrator, *L.*	+
0	Mergus cucullatus, *L.*
„ albellus, *L.*	+

M. Serrator is indigenous, nestling on islets both of marine and fresh-water loughs. *M. Merganser* is a regular, and *M. albellus* an occasional winter visitant.

M. cucullatus has a place in the British catalogue from the occurrence of a single specimen.

Fam. *Colymbidæ.*

Ireland.	*Great Britain.*
Podiceps cristatus, *Lath.*	+
„ rubricollis, *Lath.*	+
„ cornutus, *Lath.*	+
„ auritus, *Lath.*	+
„ minor, *Lath.*	+
Colymbus glacialis, *L.*	+
„ arcticus, *L.*	+
„ septentrionalis, *L.*	+

Pod. minor is common and resident; *P. cristatus* is more rare, but resident on the larger lakes; *P. rubricollis* is known only as a rare visitant; *P. cornutus* is not of uncommon occurrence in winter, at which season *P. auritus* more rarely occurs. These two last species are most probably indigenous, as in England, but they have not come under my cognizance in summer. *Col. glacialis* and *C. septentrionalis* are regular winter visitants; *C. arcticus* is much more rare, but occasionally met with at the same season.

* The specimen is in the collection of Mr. R. Ball.

Fam. *Alcidæ.*

Ireland.	*Great Britain.*
Uria Troile, *Lath.*	+
,, Brunnichii, *Sabine.*	+
,, Grylle, *Lath.*	+
Mergulus melanoleucos, *Ray.*	+
Fratercula arctica, *Steph.*	+
Alca Torda, *L.*	+
,, impennis, *L.*	+

Uria Grylle is a resident species. *U. Troile, Frat. arctica*, and *Alca Torda*, are regular summer visitants, having breeding-haunts around the coast: either or both of the two former I am disposed to believe may occasionally be found in small numbers in the bays of Ireland during winter. *Uria Brunnichii* is noticed by Major Sabine as seen by him in the month of July on the coast of Kerry*, where it may be presumed to breed. By this able ornithologist, the *Merg. melanoleucos* (*M. Alle*) was observed at the same time with *U. Brunnichii*; here it also may have its nestling-places; in two instances I know of this bird having been shot on the coasts of Wexford and Kerry. Of *Alca impennis*, a single specimen is on record as Irish.

Fam. *Pelecanidæ.*

Ireland.	*Great Britain.*
Phalacrocorax Carbo, *Steph.*	+
,, cristatus, *Steph.*	+
Sula Bassana, *Briss.*	+

The first two are common and resident. *Sula Bassana* is common on the coast of Ireland in summer and autumn; the individuals which frequent the northern parts have their breeding-haunts in Scotland. On the Irish coast this species breeds only on one of the Skelig islands off Kerry.

Fam. *Laridæ.*

Ireland.	*Great Britain.*
0	Sterna Caspia, *Pall.*
Sterna Boysii, *Lath.*	+
,, Dougallii, *Mont.*	+
,, Hirundo, *L.*	+
,, arctica, *Temm.*	+
,, minuta, *L.*	+
,, nigra, *L.*	+
0	Sterna Anglica, *Mont.*
,, stolida, *L.*	0
Larus Sabini, *Sab.*	+
,, minutus, *Pall.*	+
,, capistratus, *Temm.*	+

* Ainsworth's "Caves of Ballybunian," p. 78.

Ireland.	*Great Britain.*
Larus ridibundus, *L.*	+
0	Larus atracilla, *L.*
„ Rissa, *L.*	+
„ Canus, *L.*	+
„ eburneus, *Gmel.* (?)	+
„ argentatus, *Brunn.*	+
„ fuscus, *L.*	+
„ marinus, *L.*	+
„ Islandicus, *Edmon.*	+
„ glaucus, *Brunn.*	+
Cataractes vulgaris, *Flem.*	+
„ Pomarinus, *Steph.*	+
„ Richardsonii (Lest. Richardsonii, *Sw.*)	+
„ parasiticus (*not Flem.*, Lest. parasiticus, *Temm.*)	+
0	Procellaria glacialis, *L.*
Puffinus cinereus, *Steph.*	+
„ Anglorum, *Ray.*	+
0	Puffinus fuliginosus, *Strickland.*
Thalassidroma pelagica, *Selby.*	+
„ Bullockii, *Selby.*	+

St. Dougallii, *S. Hirundo*, *S. arctica*, and *S. minuta*, are regular summer visitants to Ireland, the *S. Hirundo* and *S. arctica* being much the most common and widely-distributed species. These two, with *S. Dougallii*, breed in a small low rocky islet near the entrance to Belfast Bay*. *St. nigra* is an occasional visitant; and many years ago was known by Mr. R. Ball to breed at a small lake in the county of Cork. *St. Boysii* is annually shot upon the coast, and may perhaps have breeding-haunts in some of the islets that are rarely visited by the naturalist. *St. stolida* has a place in the catalogue from two specimens having been taken at sea between Tusker Lighthouse (co. Wexford) and Dublin Bay. *Larus capistratus* (of British authors), *L. ridibundus*, *L. Canus*, *L. argentatus*, *L. fuscus*, and *L. marinus*, are resident species. *L. Rissa* is a regular summer visitant. *L. glaucus* is of occasional occurrence on every quarter of the coast. *L. Sabini* has in four instances been obtained in the bays of Belfast and Dublin; *L. Islandicus* has twice been noticed†, and *L. minutus* once: of the latter species, an adult bird in summer plumage was shot upon the river Shannon. In the Appendix to Ross's Second Voyage it is remarked, under the head of *Larus eburneus*,

* *S. Dougallii* likewise breeds on islets off the Dublin coast.

† In March 1832 I saw a specimen of *L. Islandicus* in the shop of Mr. Glennon, bird-preserver, Dublin: it had been sent him early in the winter of 1831–32, from the West of Ireland. The other example was obtained by the Ordnance Survey in Strangford Lough.

that "this beautiful gull has lately visited the western shores of Ireland," (p. 35). Capt. James Ross, the author of this Appendix, has informed me that early in the year 1834 he derived that information from Joseph Sabine, Esq., and that he knows nothing of it further than what is published. For some years, however, I have had a note communicated by the late Thomas F. Neligan, Esq., of Tralee, who was well versed in British Birds, that "in January 1835 he saw a gull in a field near that town, and four miles from the sea, which he was satisfied was the *L. eburneus*; he watched it for about twenty minutes, and was at first attracted by the ivory tint of its plumage and its black legs." All the species of *Cataractes* do in autumn and winter, at least occasionally, visit the Irish coast. *Puffinus cinereus* has been obtained near Dungarvan, county Waterford, and is believed to breed there. *P. Anglorum* is known to me only as an occasional visitant; it would seem to be more rare now in Ireland than formerly, as is the case in other of the British islands: in Harris's Down and Smith's Cork it is mentioned. *Thal. pelagica* is at all times to be met with on the coasts of Ireland washed by the Atlantic, and breeds on several of the islets ranging from north to south of the western coast. *Thal. Bullockii* (*Proc. Leachii*, Temm.) has been obtained on various occasions in all quarters of Ireland; it breeds on some of the western islets.

Sterna Caspia and *St. Anglica* have in a very few instances been obtained in England. *Larus atracilla*, as a British bird, was known only to Montagu, who on two occasions met with it on the coast of Sussex. *Proc. glacialis* is, except in the North of Scotland, an occasional visitant to the shores of Great Britain; *P. fuliginosa* has but once been procured in England.

In the preceding catalogue of Irish Birds, all the species noticed by Mr. Selby as *indigenous* to Great Britain will be found—either as such, or as visitants—except the following: *Melizophilus provincialis*, *Parus cristatus*, *Emberiza Cirlus*, *Passer montanus*, *Picus viridis**, *Sitta europæa*, *Columba Œnas*, *Lagopus mutus*. With these may be mentioned three more which are said to have been found in Ireland, but are not now indigenous—*Picus minor*, *Tetrao Tetrix*, *Otis tarda*.

* I have been assured that this bird is found in some localities in Ireland, but have not seen specimens.

PART IV.

Class REPTILIA.

Order 1.—Testudinata.

Ireland.	*Great Britain.*
Chelonia Caouana, *Schw.*	+
0	Chelonia imbricata, *Schw.*
0	Sphargis coriacea, *Gray.*

A single specimen of *C. Caouana* has been taken alive on the coast of Donegal*. In the British catalogue this species has a place from the occurrence of an individual on the Devonshire coast.

C. imbricata and *S. coriacea* have each been obtained on three occasions on the coasts of Great Britain.

Order 2.—Sauria.

Ireland.	*Great Britain.*
0	Lacerta agilis, *L. Bell.*
Zootoca vivipara, *Wagl. Bell.*	+

Z. vivipara prevails over the island. *Lacerta viridis,* stated by Ray to have been found in Ireland, is at present quite unknown. Mr. Bell in his "British Reptiles" suggests that "a green variety of *L. agilis,* L., was probably alluded to: this is more likely than that the true *L. viridis* was meant; but the *L. agilis,* L., has not been distinguished as an Irish species." It has but lately been added to the British Fauna, and from specimens obtained in the South of England.

Order 3.—Ophidia.

Ireland.	*Great Britain.*
0	Anguis fragilis, *L.*
0	Natrix torquata, *Ray.*
0	Pelius Berus, *Merr.*

Ireland has ever been free from the presence of Ophidian Reptiles. As there is no physical obstacle to their being indigenous to the island, it can only be said, that as all animals have geographical limits assigned to them, so these have Great Britain as their western boundary within her parallel of latitude.

* See Annals of Natural History, vol. v. p. 8.

AMPHIBIA.

Ireland.	*Great Britain.*
Rana temporaria, *L.*	+
0	Bufo vulgaris, *Laur.*
Bufo calamita, *Laur.*	+
Triton cristatus, *Laur.* (?)	+
0	Triton Bibronii, *Bell.*
Lissotriton punctatus, *Bell.*	+
„ palmipes, *Bell.* (?)	+

Rana temporaria is common throughout Ireland. In Rutty's "Natural History of Dublin," the Frog is said to have been "brought into this kingdom in 1699 by Dr. Guithers:" from those introduced by this gentleman to the University Park, Dublin, it is considered that all the frogs in Ireland and her islands* owe their origin! *Bufo calamita* is found in several parts of the county of Kerry, where it is believed to be indigenous. *Triton cristatus* is noticed by Templeton; to myself it is unknown. *Liss. punctatus* occurs from north to south, but is not universally distributed. *Liss. palmipes* has been so accurately described to me as to warrant its introduction, with a mark of doubt: I have not yet seen examples of it.

Bufo vulgaris, though so common in Great Britain, is not found in Ireland. *Triton Bibronii* is a recently-distinguished British species.

PART V.

Class PISCES.

(1. Ossei.)

PECTINIBRANCHII.

Order 1.—Acanthopterygii.

Fam. *Percidæ.*

Ireland.	*Great Britain.*
Perca fluviatilis, *L.*	+
Labrax Lupus, *Cuv.*	+
0	Serranus Cabrilla, *Cuv.*
0	„ Gigas, *Cuv.*
0	Polyprion cernium, *Cuv.*
0	Acerina vulgaris, *Cuv.*
0	Trachinus Draco, *L.*
Trachinus Vipera, *Cuv.*	+
Mullus Surmuletus, *L.*	+
0	„ barbatus, *L.*

* In Achil I have remarked them to be common.

In the family *Percidæ*, Ireland would seem to be so deficient that four species only can be announced; of these, *Mullus Surmuletus* is given on the authority of Dr. Patrick Browne's Catalogue, published in 1774. The *Perca fluviatilis* is stated to have been introduced; but this I am disposed to doubt, as the species is so very widely distributed over the island. *Labrax Lupus* is a well-known fish on the coast, its numbers decreasing northwards. *Trachinus Vipera* is found from north to south.

Of the species unknown to the Irish Fauna, *Serranus Cabrilla* and *S. Gigas* have in Great Britain been noticed only on the coast of Cornwall, and of the latter but a single individual has been procured; *Polyprion cernium* has been observed only on the south-west coast of England; *Mullus barbatus* is extremely rare; *Trachinus Draco* a species only of occasional occurrence, and chiefly on the southern coast*. *Acerina vulgaris* is said to be common to the rivers and canals in England.

Fam. *Loricati*.

Ireland.	*Great Britain.*
Trigla Pini, *Bl.*	+
„ lineata, *Gmel.*	+
„ Hirundo, *Bl.*	+
„ Lyra, *L.*	+
„ Gurnardus, *L.* / „ Cuculus, *Bl.* } one species†	+
„ Pœciloptera, *Cuv.*	+
0	Trigla lucerna, *Brunn.*
0	Peristedion Malarmat, *Cuv.*
0	Cottus Gobio, *L.*
„ Scorpius, *L.*	+
„ Bubalis, *Euph.*	+
0	Cottus quadricornis, *L.*
Aspidophorus cataphractus, *Cuv.*	+
0	Scorpœna norvegica, *Cuv.*
Gasterosteus aculeatus, *L.*	+
„ Pungitius, *L.*	+
„ Spinachia, *L.*	+

Of the seventeen (reckoning *Trigla Gurnardus* and *T. Cuculus* as one) British species of *Loricata* here enumerated, Ireland is known to possess all but five; of these, three species, *Trigla lucerna, Peristedion Malarmat,* and *Cottus quadricornis,* are late additions, and have as yet been procured only

* The term "southern coast" applied to England, throughout this Report, refers generally to the portion of that country which lies altogether to the South of Ireland.

† See Annals of Natural History, vol. ii. p. 413.

on the more southern coast. *Sciæna norvegica* has I believe been taken only from Berwick northwards. *Cottus Gobio* is said to be common in England.

Of *Trigla Pœciloptera* but a single individual, obtained at Youghal, has yet been recognised in the British seas*. Of the *Triglæ, T. Gurnardus* is most common in Ireland, and taken in abundance in the more genial season of the year; next come *T. Hirundo, T. Pini,* and *T. lineata,* which are procured at different seasons and throughout the winter. *T. Lyra* I have not seen in the north, but have observed it in Galway market. Mr. R. Ball states that at Youghal it is not uncommon. Of the *Cotti, C. Scorpius* and *C. Bubalis* are common around the coast; the latter the more so. *Aspidophorus, Gasterosteus aculeatus,* with its varieties†, and *G. Spinachia,* are common from north to south; *G. Pungitius* is obtained in the north, and in one locality at least, southwards.

Fam. *Sciænidæ.*

Ireland.	*Great Britain.*
Sciæna Aquila, *Cuv.*	+
0	Umbrina vulgaris, *Cuv.*

A single individual only of *S. Aquila* is known to have been taken on the Irish coast; about the 1st of August, 1840, it was captured within the entrance of Cork harbour.

The *Umbrina vulgaris* has but in one instance been recognised as a British fish.

Fam. *Sparidæ.*

Ireland.	*Great Britain.*
0	Chrysophrys aurata, *Cuv.*
0	Pagrus vulgaris, *Cuv.*
0	Pagellus erythrinus, *Cuv.*
0	„ Acarne, *Cuv.*
Pagellus Centrodontus, *Cuv.*	+
0	Dentex vulgaris, *Cuv.*
0	Cantharus griseus, *Cuv.*

Of the seven British species of the *Sparidæ,* I have seen only the *Pag. Centrodontus*‡ in Ireland, where it is common around the coast. A second species appears in several Irish catalogues, and *Chrysophrys* or *Pagrus* may perhaps be

* Proceedings of the Zoological Society, 1837, p. 61.

† *Gast. trachurus, semiarmatus, lieurus, brachycentrus, semiloricatus,* and *spinulosus* seem to me varieties of one species. See Annals of Natural History for April 1841.

‡ It is I presume this species which is alluded to by Templeton, under the name of *Sparus aurata.*

meant. Rutty mentions *Cantharus Rondeletii,* quoting Willoughby, fig. 5, 1, as a fish taken in Dublin Bay: the species thus referred to is the *Cantharus vulgaris**, a Mediterranean fish, and yet unrecognised as British. The reference is probably erroneous.

Dentex vulgaris and *Pag. Acarne* have their place in the British catalogue from the capture of a single individual of each species; the other four have, with the exception perhaps of either *Chrysophrys* or *Pagrus,* been taken only on the southern coast of England. A single specimen of *Pag. erythrinus* was procured by Dr. Parnell in the Frith of Forth.

Fam. *Squamipinnati.*

Ireland.	*Great Britain.*
0	Brama Raii, *Cuv.*

This is a rare British species. It is enumerated in a list of fishes published in M'Skimmin's History of Carrickfergus, but the propriety of the application of the name to this species is doubtful.

Fam. *Scombridæ.*

Ireland.	*Great Britain.*
Scomber Scomber, *L.*	+
„ maculatus, *Couch* (?)	+
Thynnus vulgaris, *Cuv.*	+
„ Pelamys, *Cuv.*	+
0	Xiphias Gladius, *L.*
0	Neucrates Ductor, *Cuv.*
Caranx Trachurus, *Lacép.*	+
Zeus Faber, *L.*	+
0	Capros Aper, *Lacép.*
Lampris Luna, *Flem.*	+
0	Coryphæna Morio, *Cuv.*

The four species of *Scombridæ* desiderated in the Irish list are all rare British species, and, excepting *Xiphias,* chiefly found on the southern coast.

Scomber Scomber is common around Ireland; *Scomber maculatus* is stated by a very intelligent correspondent to visit the coast of Connemara in the months of July and August. *Caranx Trachurus* and *Zeus Faber* have been obtained from north to south, but are most common on the western coast. *Thynnus vulgaris, T. Pelamys,* and *Lampris Luna,* are extremely rare visitants to the Irish as to the English and Scottish coasts.

* Cuv. and Val., tom. vi. p. 318.

Fam. *Tænioidei.*

Ireland.	*Great Britain.*
0	Lepidopus argyreus, *Cuv.*
0	Trichiurus Lepturus, *L.*?
0	Trachypterus vogmarus, *Cuv.*
0	Gymnetrus Hawkenii, *Bl.*?
0	Cepola rubescens, *L.*

Of the *Tænioidei*, none can be announced as Irish; all are species of only occasional occurrence on the coasts of Great Britain, excepting the *Cepola rubescens*, which will doubtless yet be added to the Irish catalogue. On the coast of Ayrshire, in Scotland, so near to Ireland, it has several times been taken.

Fam. *Mugilidæ.*

Ireland.	*Great Britain.*
Mugil Chelo, *Cuv.*	+
„ Capito, *Cuv.*	M. curtus, *Yarr.*
Atherina Presbyter, *Cuv.*	+

Of the *Mugilidæ* we probably want only *Mugil curtus*, of which but one British specimen has been obtained. *Mug. Capito* has been noticed as Irish, but all the specimens which have come under my own examination were *M. Chelo*, which is our common Mullet of the north*. *Atherina Presbyter* is taken from north to south.

Fam. *Gobiadæ.*

Ireland.	*Great Britain.*
0	Blennius ocellaris, *Bl.*
Blennius Gattorugine, *Mont.*	+
„ Yarrellii, *Val.*	+
0	„ Galerita, *Mont.*
„ Pholis, *L.*	+
Muræνoides guttata, *Lacép.* (Blen. Gunnellus).	+
Zoarces viviparus, *Cuv.*	+
Anarrhicas Lupus, *L.*	+
Gobius niger, *Cuv.* and *Val.*	0
„ Britannicus, *Thomp.* (G. niger, recent British authors).	+
„ Ruthensparii, *Euph.* (G. bipunctatus, *Yarr.*)	+
„ minutus, *Pall.*	+
„ gracilis, *Jenyns.*	+
„ unipunctatus, *Parnell.*	+
0	Gobius albus, *Parnell.*

* Capt. Portlock informs me that he submitted drawings of a Mugil taken on the coast of Down or Antrim to Mr. Yarrell, who considered them to represent *M. Capito.*

Ireland.	*Great Britain.*
Callionymus Lyra, *L.*	+
„ Dracunculus, *L.*	+

Of our desiderata here, the *Blennius ocellaris* and *B. Galerita* are rare and apparently local on the coast of Great Britain; the *Gobius albus* has been taken only in the Solway Firth, and but on one occasion.

In Ireland, the *Blennius Pholis* and *Murænoides guttata* are very common around the coast; the *B. Gattorugine* is of occasional occurrence in the north; the *B. Yarrellii* (*B. palmicornis* of Yarrell's and Jenyns's works) has been obtained on the Antrim coast by the Ordnance Survey. By Templeton the *Zoarces* was noticed in one instance; but little is known with certainty of *Anarrhicas* as an Irish fish. Of the genus *Gobius*, the *G. minutus* and *G. Ruthensparii* (*G. bipunctatus*, Yarr.) are the most widely diffused in their very different places of abode on our coasts, the former, as elsewhere, the more abundant; *G. niger* and *G. Britannicus* * I have only from the more southern portion of the island; *G. gracilis* and *G. unipunctatus* are of occasional occurrence with *G. minutus*. *Callionymus Lyra* and *C. Dracunculus* are not unfrequently taken from north to south, the latter the more commonly.

Fam. *Lophiidæ*.

Ireland.	*Great Britain.*
Lophius Piscatorius, *L.* (common).	+

Fam. *Labridæ*.

Ireland.	*Great Britain.*
Labrus variabilis, *Thomp.*† (L. maculatus, *Bloch.*)	+
„ lineatus, *Don.* (not specifically distinct from the last).	+
0	Labrus Comber, *Gmel.*
„ variegatus, *Gmel.*	+
0	„ Vetula, *Bl.*?
„ trimaculatus, *Penn.*‡	+
0	Julis vulgaris, *Flem.*
Crenilabrus Tinca, *Flem.* } one species§.	+
„ Cornubicus, (Labrus Cornubicus, *Penn*). } one species§.	+
„ gibbus, *Flem.* } one species§.	+

* Zoological Proceedings, 1837, p. 61.

† Zoological Proceedings, 1837, p. 59.

‡ M. Agassiz informs me that *L. carneus*, Risso, of which he possesses a specimen so named by that author, is a distinct species from the *L. carneus*, Bloch; this latter being identical with *L. trimaculatus* as figured by Donovan.

§ Magazine of Zoology and Botany, vol. ii. p. 442.

Ireland.	Great Britain.
0	Crenilabrus luscus, *Couch.*
Crenilabrus rupestris, *Selby.*	+
„ pusillus, *Yarr.*	+
„ exoletus, *Yarr.*	+

Of the British *Labridæ* wanting to the Irish list, the *L. Comber* is a very obscure and little-understood species. *Labrus Vetula, Julis vulgaris*, and *Crenilabrus luscus*, have each but in a single instance been obtained on the British coast.

Labrus variabilis and *Cren. Tinca* are common in suitable localities around the Irish coast; *Lab. variegatus* is as extensively distributed, but in very small numbers; *Lab. trimaculatus* has been taken by the collectors of the Ordnance Survey at Portrush near the Giant's Causeway. Of *Cren. rupestris, C. exoletus*, and *C. pusillus*, a few individuals have been procured—the first-mentioned on the north-east and west coast, the second on the north-east, and the last on the south only.

Fam. *Centriscidæ.*

Ireland.	Great Britain.
0	Centriscus Scolopax, *L.* (extremely rare.)

Order 2.—MALACOPTERYGII.

Fam. *Cyprinidæ**.

Ireland.	Great Britain.
0	Barbus vulgaris, *Flem.*
Gobio fluviatilis, *Will.*	+
Tinca vulgaris, *Cuv.* (?)	+
Abramis Brama, *Cuv.*	+
0	Abramis Blicca, *Cuv.*
„ Buggenhagii, *Thomp.* (Cyprinus Buggenhagii, *Bl.*)	+
0	Leuciscus Rutilus, *Cuv.*
0	„ Dobula, *Cuv.*
0	„ vulgaris, *Cuv.*
0	„ Lancastriensis, *Yarr.*
0	„ cephalus, *Flem.*
Leuciscus erythrophthalmus, *Cuv.*	+
0	„ cœruleus, *Yarr.*
0	„ Alburnus, *Cuv.*
0	„ Phoxinus, *Cuv.*
0	„ Idus, *Cuv.*
Cobitis barbatula, *L.*	+
0	Cobitis Tænia, *L.*

In the *Cyprinidæ* Ireland would seem to be remarkably deficient; and although there is no doubt that some species

* The naturalized species are omitted.

will yet be added to our list, I have little hesitation in considering the waters of this country as deficient in the fishes of this family.

Gobio fluviatilis, *Abramis Brama*, and *Leuciscus erythrophthalmus* are common, and widely diffused over the island. *Cobitis barbatula* is somewhat generally distributed; *Abramis Buggenhagii* has as yet been observed only in the river Lagan. *Cyprinus Carpio* and *Tinca vulgaris* are in some waters in the country; but even the latter, which is considered indigenous to England, is stated to have been introduced to Ireland. *Leuciscus Phoxinus* was introduced some years ago near Dublin, and has, I understand, thriven well there*.

Fam. *Esocidæ.*

Ireland.	*Great Britain.*
Esox Lucius, *L.*	+
Belone vulgaris, *Cuv.*	+
Scomberesox Saurus, *Flem.*	+
0	Hemiramphus europæus, *Yarr.*
Exocœtus exiliens, *Bl.* (? Irish species).	+

The two first mentioned are common; the *Scomberesox* is apparently rare; *Exocœti* have been observed on the southern coast, but specimens are not available, that the species might be determined. The fish named provisionally *Hemiramphus europæus* has not yet been noticed on the Irish coast†.

Fam. *Salmonidæ.*

Ireland.		*Great Britain.*
Salmo Salar, *L.*		+
„ Eriox, *L.*		+
„ Trutta, *L.*		+
„ Fario, *L.*		+
„ ferox, *Jard.*		+
„ Umbla, *L.*	one species, W. T.	+
„ Salvelinus, *Don.*		+
Osmerus Eperlanus, *Flem.*		+
0		Osmerus hebridicus, *Yarr.*
0		Thymallus vulgaris, *Cuv.*
0		Coregonus Lavaretus, *Flem.*

* In Rutty's Dublin (1772) it is remarked of the *Cyprinus Carpio*, that "it is said to have been first introduced into Ireland in the reign of King James the First." In the same work it is said of *Tinca vulgaris*, that it, like the Carp, "is found for the most part in ponds, and rarely in the Liffey and Donnybrook rivers." "*Cyprinus Cephalus* and *C. Barbus*" appear in Dr. P. Browne's list of Irish Fishes, but excepting their names no information is given.

† *Silurus Glanis*, L., a fish described to me as taken some years ago in a river flowing into the Shannon near its source, exactly agrees with this species. For particular notice see Annals of Natural History, vol. vii.

Ireland.	*Great Britain.*
Coregonus Pollan, *Thomp.*	0
0	Coregonus Willughbei, *Jard.*
0	„ Lacepedei, *Parnell.*
0	Scopelus Humboldtii, *Cuv.*

Of the genus *Salmo*, Ireland possesses all the British species. There are many valuable fisheries for *S. Salar* around the coast; of the migratory species, *S. Trutta* is next in value, and is taken co-extensively with it; the distribution of *S. Eriox* is yet to be determined; on every side of the northern portion of the island it occurs. *S. ferox* is common to the larger lakes, as is *S. Fario* to the rivers and lakes throughout the island. *Salmo Umbla* or *S. Salvelinus* (for I regard the fish so called but as one species) inhabits suitable lakes in all quarters. The *Osmerus Eperlanus* is recorded by Templeton as a fish of occasional occurrence. *Coregonus Pollan*, as yet known only as an Irish species, inhabits Lough Neagh, Erne, and Derg, and is abundant in the first-named locality.

Of the six species of British *Salmonidæ*, as yet unknown as Irish, three, *Osmerus hebridicus*, *Coregonus Willughbei*, and *Cor. Lacepedei*, are each known only to a single locality; *Scopelus Humboldtii* (if such be the species) has been recorded but in three instances on the coast of Great Britain; *Thymallus* is very local in England. This is noticed in Rutty's Dublin, but evidently in error, as it is made " a sea-fish." Dr. P. Browne enumerates it, perhaps without any better reason; he published in 1774, Rutty in 1772. *Coregonus Lavaretus* (if properly so named) is found only in Bala Lake in Wales, and some of the northern English lakes.

Fam. *Clupeidæ.*

Ireland.	*Great Britain.*
Clupea Harengus, *L.*	+
0	Clupea Leachii, *Yarr.*
„ Sprattus, *L.*	+
0	„ alba, *Yarr.*
„ Pilchardus, *Bl.*	+
Alosa Finta, *Cuv.*	+
„ communis, *Cuv.*	+
0	Engraulis Encrasicholus, *Flem.*

Clupea Leachii and *C. alba* have not yet been identified as Irish species; nor has the *Engraulis*, which is of rare occurrence on the English coast, been noticed on the Irish.

Clupea Harengus, *C. Sprattus*, and *C. Pilchardus* prevail around the coast, the last-named in the south particularly; here also the *Alosa Finta* is chiefly found. The " Rock Herring," which according to Dr. Parnell is the name applied in

Scotland to the *Alosa Finta*, is enumerated among the Fishes of Londonderry in Sampson's History of that county. It is however the *A. communis* which is noticed in the Ordnance Survey of Londonderry, and as being "not uncommon."

Div. 2.—SUBBRACHIALES.

Fam. *Gadidæ*.

Ireland.	*Great Britain.*
Gadus Morrhua, *L.*	+
" Callarias, *L.*	+
" Æglefinus, *L.*	+
" luscus, *L.*	+
" minutus, *L.*	+
Merlangus vulgaris, *Cuv.*	+
" Pollachius, *Cuv.*	+
" Carbonarius, *Cuv.*	+
0 ?	Merlangus virens, *Cuv.*
Merlucius vulgaris, *Cuv.*	+
Lota Molva, *Cuv.*	+
0	Lota vulgaris, *Cuv.*
Motella tricirrhata, *Nills.*	+
" Mustela, *Nills.*	+
0	Motella Cimbrica, *Nills.*
Brosmus vulgaris, *Cuv.* (?)	+
Phycis furcatus, *Cuv.*	+
Raniceps trifurcatus, *Flem.*	+
0	Couchia argenteola, *Thomp.* (Motella glauca, Gadus argenteolus, *Mont.*)
Couchia minor, *Thomp.*	0

Of the four British species of the *Gadidæ* which we seem to want, one, *Motella Cimbrica* is a recent addition to the catalogue, and is yet known only to two localities, both in Scotland; *Lota vulgaris* is very partially distributed in England; *Couchia argenteola** has been observed only in Devonshire and Cornwall; *Merlangus virens* is unknown to me as a species distinct from *M. Carbonarius*. Of *Brosmus vulgaris* I have not seen an Irish specimen, but it is in the list of Fishes given in M'Skimmin's History of Carrickfergus.

Gadus Morrhua and *G. Æglefinus* are common around the Irish coast. *Gad. luscus, G. Callarias,* and *G. minutus* are of occasional occurrence from north to south. *Merlangus vulgaris, M. Pollachius* and *M. Carbonarius* are common and generally distributed. *Merlucius vulgaris* is taken around the coast, but is much more common in the south. *Lota Molva* and the two common *Motellæ* are generally distributed. *Phy-*

* Annals of Natural History, vol. ii. p. 411.

cis furcatus has but rarely been obtained, and of *Raniceps trifurcatus* a single individual is on record. *Couchia minor* has been captured only in Strangford Lough*.

Fam. *Pleuronectidæ*.

Ireland.	*Great Britain.*
Platessa vulgaris, *Cuv.*	+
„ Flesus, *Cuv.*	+
„ Limanda, *Cuv.*	+
„ microcephala, *Flem.*	+
„ Pola, *Cuv.*	+
0	Platessa Limandoides, *Jen.*
0	„ elongata, *Yarr.*
Hippoglossus vulgaris, *Cuv.*	+
Pleuronectes maximus, *L.*	+
„ Rhombus, *L.*	+
„ punctatus, *Bl.*	+
„ hirtus, *Mull.*	+
„ Megastoma, *Don.*	+
0	Pleuronectes Arnoglossus, *Schn.*
Solea vulgaris, *Cuv.*	+
0	Solea Pegusa, *Yarr.*
„ Lingula, *Rond.*	+
„ variegata, *Flem.*	+

All but four species of the British *Pleuronectidæ* have been noticed on the coast of Ireland; of these the *Platessa Limandoides* and *Plat. elongata* are late additions to the British catalogue; the former has been taken on the eastern coast of Scotland and South of England; the latter but in one instance, and a single specimen at Bridgewater. *Pleuronectes Arnoglossus*†, and *Solea Pegusa* are species of occasional occurrence, and, as British, are known only to the southern coast of England.

Platessa vulgaris, P. Flesus and *P. Limanda* are common around the Irish coast, the last not numerous; *P. microcephala* is widely distributed, but in numbers very limited. *P. Pola* appears to be a local fish, but tolerably numerous where it does occur; from the eastern coast only have I seen specimens. *Hippoglossus vulgaris* is occasionally met with from north to south. *Pleuronectes maximus* and *P. Rhombus* are common around the coast; *P. Megastoma* is not of unfrequent occurrence; *P. punctatus* and *P. hirtus* have each been once obtained in the north-east of the island. *Solea vulgaris* is common around the coast; *S. Lingula* I have seen a few specimens of from every side of the island; *S. variegata* has been taken in Belfast Bay.

* Annals of Natural History, vol. ii. p. 408.

† This is enumerated in M'Skimmin's list, but probably erroneously.

Fam. *Discoboli.*

Ireland.	*Great Britain.*
Lepadogaster Cornubiensis, *Flem.*	+
,, bimaculatus, *Flem.*	+
,, cephalus, *Thomp.*	0
Cyclopterus Lumpus, *L.*	+
Liparis vulgaris, *Flem.* (?)	+
,, Montagui, *Flem.*	+

In this family Ireland would seem to possess one species more than Great Britain, *Lepadogaster cephalus,* which was described from a specimen taken on the western coast*. *Lepadogaster Cornubiensis* is a local species known to inhabit the coasts of Antrim and Clare; *L. bimaculatus* is taken on the eastern and western coasts by dredging in deep water; *Cyclopterus Lumpus* is common from north to south. Of *Liparis vulgaris* I have not seen any Irish specimen; it is stated in the Ordnance Survey of Londonderry to have been procured at "Lough Foyle and Larne†;" of *L. Montagui,* I have seen a few specimens which were taken on every side of the island.

Fam. *Echeneidæ.*

Ireland.	*Great Britain.*
0	Echeneis Remora, *L.* (taken in a single instance.)

Div. 3.—APODES.

Fam. *Anguillidæ.*

Ireland.	*Great Britain.*
Anguilla acutirostris, *Yarr.*	+
,, latirostris, *Yarr.*	+
,, mediorostris, *Yarr.* (?)	+
Conger vulgaris, *Cuv.*	+
0	Muræna Helena, *L.*
Leptocephalus Morrissii, *Penn.*	+
Ophidium imberbe, *L.* (?)	+
Echiodon Drummondii, *Thomp.*	0
Ammodytes Tobianus, *L.*	+
,, Lancea, *Cuv.*	+

The *Muræna Helena* only of the British *Anguillidæ* is certainly wanting to the Irish catalogue; there is but one recorded instance of its capture on the coast of Great Britain.

The *Echiodon,* of which a single individual was discovered on the Irish coast, has not yet been met with elsewhere. *An-*

* Annals of Natural History, vol. iii. p. 34.

† One of these specimens, kindly offered to my inspection by Capt. Portlock, though not well marked as *L. Montagui,* I considered to be of this species.

guilla acutirostris, *A. latirostris* and *A. Conger* are common and in suitable localities, especially the first and last generally-distributed species. Of the *A. acutirostris* there are several valuable fisheries in Ireland. *A. mediorostris* is marked with doubt from a want of accordance in the one osteological character of the specimen examined with that attributed to the species; in every other character and in habit examples taken in the North of Ireland agree with it. *Leptocephalus Morrissii* has, in a few instances, been taken on the north-eastern, southern and western coasts. Templeton notices the *Ophidium imberbe* of Pennant as once obtained by him. *Ammodytes Lancea* is common on sandy coasts around the island; *A. Tobianus* has only as yet been recognised on the Down coast, where it is well known.

LOPHOBRANCHII.

Order 3.—Osteodermi.

Fam. *Syngnathidæ*.

Ireland.	*Great Britain.*
Syngnathus Acus, *L.*	+
„ Typhle, *L.*	+
„ æquoreus, *L.*	+
„ anguineus, *Jenyns* ("S. Ophidion, *Bloch.*")	+
0	Syngnathus Ophidion, *L.*
„ lumbriciformis, *Jenyns.*	+
Hippocampus brevirostris, *Cuv.*?	+

All of the British *Syngnathidæ* except *S. Ophidion*, Linn., are known as Irish. *Syng. Acus* and *S. lumbriciformis* are the most common around the coast. *S. Typhle*, *S. æquoreus*, and *S. anguineus* may be considered as rare, but have been taken both in the north and south. There is indubitable evidence of the occurrence of the genus *Hippocampus* more than once on the Irish coast, but the species cannot be announced: I have not myself seen any examples.

Order 4.—Gymnodontes.

Fam. *Gymnodontidæ*.

Ireland.	*Great Britain.*
Tetrodon stellatus, *Don.*	+
Orthagoriscus Mola, *Schn.*	+
0	Orthagoriscus oblongus, *Schn.*

Templeton has recorded the occurrence of *Tetrodon stellatus* in one instance on the coast of Waterford. *Orthagoriscus Mola* has occasionally been captured on every side of the island; *O. oblongus* has not been recognised as an Irish fish.

Order 5.—SCLERODERMI.

Ireland.	Great Britain.
0	Balistes Capriscus, *Gmel.* (a single specimen.)

II. CARTILAGINEI.

Order 6.—ELEUTHEROPOMI.

Ireland.	Great Britain.
Acipenser Sturio, *L.* (?)	+
„ Thompsoni, *Ball, MS.*	0
0	Acipenser latirostris, *Parnell.*

Mr. R. Ball is of opinion that one or two Irish examples of *Acipenser*, which he has critically examined, are not only distinct from the two species which have been recognised as British, but are undescribed: he has named the species *A. Thompsoni*, and is about to publish a communication on the subject in the Proceedings or Transactions of the Royal Irish Academy. Sturgeons are occasionally, though very rarely, taken in all the larger rivers of Ireland, but I have not had the opportunity of examining them critically as to species.

Order 7.—ACANTHORRHINI.

Ireland.	Great Britain.
0	Chimæra monstrosa, *L.* (taken only in the Shetland Islands).

Order 8.—PLAGIOSTOMI.

Fam. *Squalidæ.*

Ireland.	Great Britain.
Scyllium Canicula, *Cuv.*	+
„ stellaris, *Cuv.*	+
Pristiurus melanostomus, *Bonap.* (Scyllium melanostomum, *Bon.*)	+
0	Carcharias vulgaris, *Cuv.*
Carcharias Vulpes, *Cuv.* (?)	+
„ glaucus, *Cuv.*	+
Lamna Cornubica, *Cuv.* „ Monensis, *Cuv.* } one species?	+
Galeus vulgaris, *Cuv.*	+
Mustelus lævis, *Cuv.*	+
Selachus maximus, *Cuv.*	+
Spinax acanthias, *Cuv.*	+
0	Scymnus borealis, *Flem.*
0	Echinorhinus spinosus, *Blainv.*
0	Zygæna malleus, *Val.*
Squatina Angelus, *Dum.*	+

Of the four *Squalidæ* which cannot be announced as Irish, the

Carcharias vulgaris has not been properly established as a British species; the *Zygæna malleus* has but once been taken; *Scymnus borealis* twice, and in both instances north of the mainland of Scotland. *Echinorhinus spinosus* is a late addition to the British catalogue, and has been obtained in different localities on the English coast.

Scyllium Canicula, *Spinax acanthias*, *Mustela lævis* and *Galeus vulgaris* are the most common species; the first the most so, the others becoming less so in the order in which they are set down. They are found from north to south. *Carcharias glaucus*, *Lamna Cornubica* or *Monensis* (these I am disposed to believe are but one species), and *Squatina Angelus* are of occasional but rare occurrence from north to south. Templeton notices *Scyllium stellare* as taken occasionally; and *Carcharias Vulpes* as having been seen about the Copeland Isles, near the entrance of Belfast Bay. *Selachus maximus*, the "Sunfish" of Ireland, and so valuable for its oil, prevails on the western and southern coasts, but chiefly on the former. Of the *Pristiurus melanostomus*, two individuals have been obtained by the collectors of the Ordnance Survey at Portrush, near the Giant's Causeway*.

Fam. *Raiidæ*.

Ireland.	*Great Britain.*
Torpedo Walshii, *Thomp. MS.*	+
Raia Batis, *L.*	+
„ Oxyrhynchus, *Mont.* (Smith's Waterford.)	+
0	Raia marginata, *Flem.*
„ chagrinea, *Mont.*	+
„ maculata, *Mont.*	+
0	„ microcellata, *Mont.*
„ clavata, *Will.*	+
0	„ radiata, *Don.*
0	„ intermedia, *Parnell.*
„ radula, *Delar.*†	+
Trygon Pastinaca, *Cuv.*	+

* Captain Portlock, in contributing a notice of this Shark, observed, that "in the work of Müller and Henle the genus *Pristiurus*, Bonap. is described as having a row of small prickles on the tail-fin, and *Scyllium Artedi* is figured and described by Risso as having but a single row. In Yarrell's description of *Scyll. melanostomum*, two rows are mentioned, and in our specimens they certainly exist. Ought not, therefore, the single row to be dropped as a generic character, and Risso's termination of his specific characters used, viz. '*pinna dorsi extremitate* [*supra*] *spinosa*'? May not the one and two-roed individuals be of distinct species, and the black mouth be common to both?"

† Captain Portlock informs me that accurate drawings of a species of Ray, obtained during the Ordnance Survey of Antrim, and submitted to Mr. Yarrell and Mr. Couch, were considered by these naturalists to represent this species.

Ireland.	*Great Britain.*
0 ?	Myliobatis Aquila, *Cuv.*
Cephaloptera Giorna, *Risso.*	0

Of our desiderata in this family, *R. marginata* and *R. radiata* are rare species, and only of occasional occurrence, the former on the English, the latter on the Scottish coast. Of *R. microcellata* and *Myliobatis Aquila,* not more than two or three British examples are on record. *Raia intermedia* is one of Dr. Parnell's recent additions from the Frith of Forth.

Raia clavata, R. Batis, and *R. maculata* are taken from north to south of Ireland; the first is the most common on the north-east coast. *R. Oxyrhynchus* is included from being noticed in Smith's History of Waterford. *R. chagrinea* and *R. radula* are additions made to our catalogue by the Ordnance Survey, and have both been taken on the north-east coast. In contributing these species Captain Portlock remarks, that "the former seems to take the place of *R. Oxyrhynchus* on the northern coast," and that of *R. radula* he lately saw a specimen which was procured in Dublin Bay. The *Torpedo,* of which I have seen Irish specimens, is identical with that from the coast of France, figured by Walsh in the Philosophical Transactions; and which in the present confused state of the genus, it might be desirable, for the sake of distinction, to term *Torpedo Walshii**. *Cephaloptera Giorna* has a place in the *general* British catalogue from a single individual taken on the southern coast of Ireland. The Rays are less known in Ireland than most other fishes, in consequence of their being rarely brought to market, and when so to their being in an imperfect state.

Order 9.—Cyclostomi.

Fam. *Petromyzidæ.*

Ireland.	*Great Britain.*
Petromyzon marinus, *L.*	+
,, fluviatilis, *L.*	+
,, Planeri, *Bl.*	+
Ammocoetes branchialis, *Cuv.*	+
Myxine glutinosa, *L.*	+

In this family Ireland possesses all the British species. *P. marinus* ascends several of the rivers around the coast. *P. Planeri* occurs from north to south, and is more common than *P. fluviatilis*. *Ammocoetes branchialis* is likewise widely distributed. *Myxine* is said by Templeton to have been found at Carrickfergus.

* For a particular notice on this subject, see Annals of Nat. Hist. vol. v. p. 292.

Finally, the species of *Vertebrata* which appear at present to be peculiar to Ireland, are six in number; two Mammals, *Mus hibernicus* (not yet properly established as a species) and *Lepus hibernicus*; and four Fishes, *Coregonus Pollan, Couchia minor*†, *Lepadogaster cephalus*, and *Echiodon Drummondii*. Further investigation will, in all probability, show that some of these species are found elsewhere.

PART VI.

Conclusion.

In addition to the foregoing comparative catalogue, it has been thought desirable that a catalogue proper, or one containing the Irish species only, should be appended to this Report. It here follows, and with it are local lists:—of these, a few more could have been given, but the six which are introduced comprise all that were considered necessary for the present purpose. The idea of giving these occurred so late, that there was not time to perfect them, but in so far as they extend they are believed to be critically correct. The columns headed "Elsewhere in North," &c. are added for the reception only of such species as are *not* found in the restricted localities comprised in the one or two preceding columns. For the Belfast list I am myself accountable, together with the greater part of what is contained in the columns headed "Elsewhere," &c. The list for "N. W. Donegal" is derived from Mr. John Vandeleur Stewart's contribution to the 5th vol. of the Magazine of Natural History on the Mammalia and Birds of that district: additions made since its publication have been kindly communicated to me by Mr. Stewart, and are included; at his desire likewise some two or three species noticed in his published catalogue are here omitted. The lists for Dublin and Youghal were contributed by Mr. Robert Ball. "West of Connaught" is derived from different sources; "Tralee" from a list favoured me some years ago by an ardent and accurate naturalist, Mr. Thomas F. Neligan, since deceased. The distance of twenty miles round Belfast, Dublin, and Youghal is comprised in the respective catalogues. The ? throughout the columns implies doubt as to species, and not as to habitat; the * denotes presence.

† Mr. Yarrell, perhaps judiciously, considers this too minute to be satisfactorily characterised as a species. The difference, however, in size between it and *Gadus argenteolus*, Mont., is so trivial, that if the one be acknowledged, the other has all but equal claims to be so.

	North.			East.		West.		South.		
MAMMALIA.	Belfast.	N.W. Donegal.	Elsewhere in North.	Dublin.	Elsewhere in East.	West of Connaught.	Elsewhere in West.	Youghal.	Tralee.	Elsewhere in South.
Vespertilio Pipistrellus	*	*	...	*	...	*	...	*	*	
Plecotus auritus	*	*	...	*	...	...	...	*	*	
Erinaceus europæus	*	*	...	*	...	*	...	*	*	
Sorex rusticus	*	*	...	*	...	...	...	*		
—— Tetragonurus	...	...	*							
Meles Taxus	*	*	...	*	...	*	...	*	*	
Lutra vulgaris	*	*	...	*	...	*	...	*	*	
Mustela vulgaris[a]										
—— erminea	*	*	...	*	...	*	...	*	...	*
Martes Foina	*									
—— Abietum	*	*	...	...	...	*	...	*?	*?	
Vulpes vulgaris	...	*	*	*	...	*	...	*	*	
Mus sylvaticus	*	*	...	*	...	*	...	*	...	*
—— Musculus	*	*	...	*	...	*	...	*	*	
—— Rattus[a]										
—— hibernicus	*	...	...	...	...	...	...	*		
—— decumanus	*	*	...	*	...	*	...	*	*	
Lepus hibernicus	*	*	...	*	...	*	...	*	*	
—— Cuniculus	*	*	...	*	...	*	...	*	*	
Cervus Elaphus	...	...	...	...	...	*	...	...	...	*
Phoca vitulina	*	*	...	*	...	*	...	*	...	*
Halichærus Gryphus	*	...	...	*	...	*	...	*		
Delphinus Delphis	*	...	...	*	...	...	...	*		
Phocæna communis	*	*	...	*	...	*	...	*		
—— Orca	*	...	...	*[b]	...	*?				
—— melas	...	...	...	...	...	*	...	*		
Hyperoodon Butzkopf	*	...	...	*						
Physeter macrocephalus? ...	...	...	*	*[b]	...	...	...	*		
—— Tursio	...	...	...	...	...	*[c]				
Balæna Mysticetus	...	*	*	...	...	*				
Balænoptera Boops (" Balæna rostrata")	...	...	...	...	...	*				
AVES.										
Aquila Chrysaëtos	*	*	...	...	*	*	...	...	...	*
Haliæetus albicilla	*	*	...	*	...	*	...	*	...	*
Pandion Haliæetus	...	...	...	*	...	*	...	...	...	*
Astur palumbarius?[a]										
Accipiter fringillarius	*	*	...	*	...	*	...	*	*	
Falco grœnlandicus	...	*								
—— Islandicus?	*									
—— peregrinus	*	*	...	*	...	*	...	*	...	*
—— Subbuteo	...	...	*	*						
—— rufipes	...	...	...	*						
—— Tinnunculus	*	*	...	*	...	*	...	*	*	
—— Æsalon	*	*	...	*	...	...	*	*	*	
Buteo vulgaris	*	*	...	*	...	*	...	*	*	
—— Lagopus	*	...	...	*						
Pernis apivorus	*	...	...	*	...	...	...	*?		
Circus rufus	*	*	...	*	...	...	...	*	*	
—— cyaneus	*	*	...	*	...	*	...	*	*	

[a] See preceding remarks on. [b] Rutty's Dublin. [c] Templeton.

AVES.	North.			East.		West.		South.		
	Belfast.	N.W. Donegal.	Elsewhere in North.	Dublin.	Elsewhere in East.	West of Connaught.	Elsewhere in West.	Youghal.	Tralee.	Elsewhere in South.
Milvus Ictinus [a]	*									
Bubo maximus	...	*								
Otus vulgaris	*	*	...	*	...	*	...	*	*	
—— Brachyotos	*	*	...	*	...	...	...	...	*	*
Scops Aldrovandi	...	...	...	...	*					
Surnia nyctea	*	...	*							
Strix flammea	*	*	...	*	...	...	...	*	...	*
Ulula stridula [a]	*									
Lanius Excubitor	*	...	...	...	...	...	...	...	...	*
Muscicapa grisola	*	...	*	*	...	...	...	...	...	*
Cinclus aquaticus	*	*	...	*	...	*	...	*	*	
Merula viscivora	*	*	...	*	...	*	...	*	*	
—— pilaris	*	*	...	*	...	*	...	*	*	
—— musica	*	*	...	*	...	*	...	*	*	
—— Iliaca	*	*	...	*	...	*	...	*	*	
—— vulgaris	*	*	...	*	...	*	...	*	*	
—— torquata	*	*	...	*	...	*	...	...	*	*
Oriolus Galbula	*	...	...	...	...	...	...	*	...	*
Accentor modularis	*	*	...	*	...	*	...	*	*	
Erythaca Rubecula	*	*	...	*	...	*	...	*	*	
Phœnicura Ruticilla	*	...	...	*						
—— Tithys	...	...	...	...	...	...	...	*		
Saxicola Œnanthe	*	*	...	*	...	*	...	*	*	
—— Rubetra	*	*	...	*	...	*	...	*	*	
—— Rubicola	*	*	...	*	...	*	...	*	*	
Salicaria Locustella [a]	*	...	...	*						
—— Phragmitis	*	*	...	*	...	*	...	*	...	*
—— arundinacea	*	...	...	*?	...	...	...	*?		
Curruca atricapilla	*	...	...	*	...	...	...	*	...	*
—— hortensis	*	...	...	...	...	...	...	...	...	*
—— cinerea	*	*	...	*	...	...	...	*	*	
Sylvia Hippolais	*	...	*	*	...	...	...	...	...	*
—— Sibilatrix ? [a]	*	...	...	*	...	...	...	...	...	*
—— Trochilus	*	*	...	*	...	...	...	*	*	
Regulus aurocapillus	*	*	...	*	...	*	...	*	*	
Parus major	*	*	...	*	...	...	...	*	*	
—— cœruleus	*	*	...	*	...	*	...	*	*	
—— palustris	*	...	...	*	...	...	...	...	...	*?
—— ater	*	*	...	*	...	...	...	*	*	
—— caudatus	*	*	...	*	...	*	...	...	...	*
Calamophilus biarmicus	...	...	...	...	...	...	*			
Motacilla Yarrellii	*	*	...	*	...	*	...	*	*	
—— Boarula	*	*	...	*	...	*	...	*	*	
—— flava	*	...	*	*						
Anthus obscurus	*	*	...	*	...	*	...	*	*	
—— pratensis	*	*	...	*	...	*	...	*	*	
—— arboreus ? [a]	*	...	...	...	...	...	...	*		
Bombycilla garrula	*	...	*	*	...	...	...	*		
Alauda arvensis	*	*	...	*	...	*	...	*	*	
—— arborea	*	...	*	*						
Plectrophanes nivalis	*	*	...	*	...	*	...	...	...	*
Emberiza miliaria	*	*	...	*	...	*	...	*	*	

[a] See preceding remarks on.

AVES.	North.			East.		West.		South.		
	Belfast.	N.W. Donegal.	Elsewhere in North.	Dublin.	Elsewhere in East.	West of Connaught.	Elsewhere in West.	Youghal.	Tralee.	Elsewhere in South.
Emberiza Schœniculus	*	*	...	*	...	...	...	*	*	
—— Citrinella	*	*	...	*	...	*	...	*	*	
Fringilla Cœlebs.	*	*	...	*	...	*	...	*	*	
—— Montifringilla	*	...	*	*	...	*	...	*		
Passer domesticus	*	*	...	*	...	*	...	*	*	
Coccothraustes vulgaris	*	*	...	*	...	...	...	...	*	
—— Chloris	*	*	...	*	...	...	...	*	*	
Carduelis elegans	*	*	...	*	...	*	...	*	*	
—— Spinus	*	...	*	*						
Linaria minor	*	*	...	*	...	...	...	*		
—— cannabina	*	*	...	*	...	*	...	*	*	
—— montana	*	...	*	*	...	...	...	...	...	*
Pyrrhula vulgaris	*	*	...	*	...	*	...	*	*	
—— Enucleator[a]	*									
Loxia curvirostra	*	...	*	*	...	...	...	*	...	*
—— leucoptera	*									
Sturnus vulgaris	*	*	...	*	...	*	...	*	*	
Pastor roseus	*	...	...	*	...	*	...	...	...	*
Fregilus Graculus	*	*	...	*	...	*	...	*	*	
Corvus Corax	*	*	...	*	...	*	...	*	*	
—— Corone	*	...	*	...	...	*	...	...	...	•
—— Cornix	*	*	...	*	...	*	...	*	*	
—— frugilegus	*	*	...	*	...	*	...	*	*	
—— Monedula	*	*	...	*	...	*	...	*	*	
Pica melanoleuca	*	*	...	*	...	*	...	*	*	
Garrulus glandarius	...	...	...	*	...	...	...	*	...	*
Picus major	*	...	*	*						
Certhia familiaris	*	*	...	*	...	...	*	*	*	
Troglodytes europæus	*	*	...	*	...	*	...	*	*	
Upupa Epops	*	...	...	*	...	...	*	*	...	*
Cuculus canorus	*	*	...	*	...	*	...	*	*	
Coccyzus americanus	...	...	...	*	...	...	...	*		
Coracias garrula	...	...	...	*	...	...	*?	...	...	*?
Merops Apiaster	...	...	...	*						
Alcedo Ispida	*	*	...	*	...	*	...	*	*	
Hirundo rustica	*	*	...	*	...	*	...	*	*	
—— urbica	*	*	...	*	...	*	...	*	*	
—— riparia	*	*	...	*	...	...	...	*	*	
Cypselus Apus	*	*	...	*	...	*	...	*	*	
—— alpinus	...	...	...	*	...	...	...	...	...	*
Caprimulgus europæus	*	...	*	*	...	...	...	*	...	*
Columba Palumbus	*	*	...	*	...	...	...	*	*	
—— Livia	*	*	...	*	...	*	...	*	*	
—— Turtur	*	*	...	*	...	...	...	*	*	
Lagopus scoticus	*	*	...	*	...	*	...	...	*	*
Perdix cinerea	*	*	...	*	...	*	...	*	*	
—— Coturnix	*	*	...	*	...	...	...	*	*	
Otis Tetrax	...	...	...	*						
Œdicnemus crepitans	...	...	...	*	...	...	...	*		
Charadrius pluvialis	*	*	...	*	...	*	...	*	*	
—— Morinellus	*	...	...	...	...	...	...	...	...	*
—— Hiaticula	*	*	...	*	...	*	...	*	*	

[a] See preceding remarks on.

AVES.	North.			East.		West.		South.		
	Belfast.	N.W. Donegal.	Elsewhere in North.	Dublin.	Elsewhere in East.	West of Connaught.	Elsewhere in West.	Youghal.	Tralee.	Elsewhere in South.
Squatarola cinerea	*	...	*	*	...	*	...	*	*	
Vanellus cristatus	*	*	...	*	...	*	...	*	*	
Strepsilas Interpres	*	*	...	*	...	...	...	...	*	
Arenaria Calidris...	*	*	...	*	...	*	...	*	*	
Hæmatopus ostralegus	*	*	...	*	...	*	...	*	*	
Ardea cinerea	*	*	...	*	...	*	...	*	*	
—— purpurea	...	...	*							
—— Garzetta	...	...	...	...	...	...	...	...	...	*
Botaurus stellaris	*	*	...	*	...	...	...	*	*	
—— minutus	*	...	*	*						
Nycticorax europæus	*?									
Platalea Leucorodia	*	...	...	...	...	...	...	*	...	*
Ibis Falcinellus	*	...	...	*?	*	...	...	*		
Numenius arquata	*	*	...	*	...	*	...	*	*	
—— Phæopus	*	*	...	*	...	*	...	*	*	
Totanus fuscus	*									
—— Calidris	*	*	...	*	...	*	...	*	*	
—— Ochropus	*	...	...	*	...	...	...	*	*	
—— Glareola?[a]	*	...	...	...	...	...	...	*		
—— Hypoleucos	*	*	...	*	...	*	...	*	*	
—— Glottis	*	...	*	*	...	*	...	...	...	*
Recurvirostra Avocetta	...	...	...	*	...	...	...	*		
Himantopus melanopterus	...	...	...	*	...	...	...	*		
Limosa melanura	*	...	...	*	...	...	*	*	...	*
—— rufa	*	*	...	*	...	*	...	*	*	
Scolopax Rusticola	*	*	...	*	...	*	...	*	*	
—— Sabini	...	...	*	...	*					
—— major?[a]	*									
—— Gallinago	*	*	...	*	...	*	...	*	*	
—— Gallinula	*	*	...	*	...	*	...	*	*	
Machetes pugnax	*	...	*	*	...	...	*			
Tringa subarquata	*	...	...	*						
—— variabilis	*	*	...	*	...	*	...	*	*	
—— maritima	...	*	*	*						
—— minuta	*	...	...	*						
—— Canutus	*	*	...	*	...	...	...	...	*	
Phalaropus lobatus	*	*	...	*						
Rallus aquaticus	*	*	...	*	...	*	...	*	*	
Crex pratensis	*	*	...	*	...	*	...	*	*	
—— Porzana	*	...	...	*	...	...	...	...	*	
Gallinula Chloropus	*	*	...	*	...	*	...	*	*	
Fulica atra	*	*	...	*	...	*	...	*	*	
Anser palustris (A. ferus *Steph.*)	...	...	...	*						
—— ferus (A. Segetum *Steph.*)	*	...	...	*	...	...	...	*		
—— Erythropus (A. albifrons, *Steph.*)	*	...	...	*	...	...	...	...	...	*
—— Bernicla	*	*	...	*	...	...	...	...	...	*
—— Brenta	*	*	...	*	...	*	...	*	*	
Cygnus ferus	*	*	...	*						
—— Bewickii	*	...	!*	*	...	*				

[a] See preceding remarks on.

AVES.	North.			East.		West.		South.		
	Belfast.	N.W. Donegal.	Elsewhere in North.	Dublin.	Elsewhere in East.	West of Connaught.	Elsewhere in West.	Youghal.	Tralee.	Elsewhere in South.
Tadorna Vulpanser	*	*	...	*	...	*	...	*	*	
Spatulea clypeata	*	...	...	*	...	...	...	...	*	
Chauliodus Strepera	...	...	...	*	...	...	...	...	...	*
Anas Boschas	*	*	...	*	...	*	...	*	*	
Querquedula acuta	*	...	...	*	...	...	...	...	*	
—— Crecca	*	*	...	*	...	*	...	*	*	
—— Circia (Anas querquedula, *L.*)	...	...	...	...	*					
Mareca Penelope	*	*	...	*	...	*	...	*	*	
Somateria mollissima	...	...	...	*						
—— spectabilis	...	...	...	*						
Oidemia fusca	...	...	...	*						
—— nigra	...	...	*	*	...	*	...	*	...	*
Fuligula ferina	*	*	...	*	...	*	...	*	*?	*
—— Marila	*	*	...	*	...	*	...	*	*	
—— cristata	*	*	...	*	...	...	...	*		
Clangula vulgaris	*	*	...	*						
Harelda glacialis	*	*	...	*						
Mergus Merganser	*	...	*	*	...	...	...	...	...	*
—— Serrator	*	*	...	*	...	*	...	...	...	*
—— albellus	*	...	...	*	...	...	*	...	...	*
Podiceps cristatus	*	...	...	*	...	*	...	...	...	*
—— rubricollis	*	...	...	...	...	...	...	...	...	*
—— cornutus	*	*?	...	*	...	...	...	...	...	*
—— auritus	*?	...	*	*?						
—— minor	*	*	...	*	...	*	...	*	*	
Colymbus glacialis	*	*	...	*	...	*	...	*		
—— arcticus	*									
—— septentrionalis	*	*	...	*	...	*	...	*	*	
Uria Troile	*	*	...	*	...	*	...	*	*	
—— Brunnichii	...	...	...	...	...	...	...	...	...	*
—— Grylle	*	*	...	*	...	*	...	*	*	
Mergulus melanoleucos	...	...	...	*	...	...	...	...	...	*
Fratercula arctica	*	*	...	*	...	*	...	*	*	
Alca Torda	*	*	...	*	...	*	...	*	*	
—— Impennis	...	...	...	...	...	...	...	...	...	*
Phalacrocorax Carbo	*	*	...	*	...	*	...	*	*	
—— cristatus	*	*	...	*	...	*	...	*	*	
Sula Bassana	*	*	...	*	...	*	...	*	*	
Sterna Boysii	*	...	...	*						
—— Dougallii	*	...	...	*	...	...	...	...	...	*
—— Hirundo	*	*	...	*	...	*	...	*	...	*
—— arctica	*	...	*	*	...	*	...	...	*	
—— minuta	*	*	...	*	...	*				
—— nigra	*	...	...	*	...	...	...	*		
—— stolida	...	...	...	...	*					
Larus Sabini	*	...	...	*						
—— minutus	...	...	...	...	...	...	*			
—— capistratus	*	...	...	*	...	*	...	...	...	*
—— ridibundus	*	*	...	*	...	*	...	*	*	
—— Rissa	*	*	...	*	...	*	...	*	*	
—— Canus	*	*	...	*	...	*	...	*	*	
—— eburneus?[a]	...	...	...	...	...	...	...	...	*	

[a] See preceding remarks on.

AVES.	North.			East.		West.		South.		
	Belfast.	N.W. Donegal.	Elsewhere in North.	Dublin.	Elsewhere in East.	West of Connaught.	Elsewhere in West.	Youghal.	Tralee.	Elsewhere in South.
Larus argentatus	*	*	...	*	...	*	...	*	*	
—— fuscus	*	*	...	*	...	*	...	*	*	
—— marinus	*	*	...	*	...	*	...	*		
—— Islandicus	*	...	...	...	...	...	*			
—— glaucus	...	*	...	*	...	...	*	*		
Cataractes vulgaris	...	...	...	*	...	...	...	* ?		
—— Pomarinus	*	...	*	*	...	...	...	*		
—— Richardsonii	...	...	...	*	...	...	...	...	...	*
—— parasiticus	*	...	...	*	...	...	...	* ?		
Puffinus cinereus	...	...	...	...	...	...	...	...	...	*
—— Anglorum	*	...	...	*	...	...	...	...	...	*
Thalassidroma pelagica	*	*	...	*	...	*	...	*	*	
—— Bullockii	*	...	...	*	...	...	...	*	...	*

	Belfast.	Elsewhere in North.	Dublin.	Elsewhere in East.	West of Connaught.	Elsewhere in West.	Youghal.	Elsewhere in South.
REPTILIA.								
Chelonia Caouana	...	*						
Zootoca vivipara } Lacerta agilis, *Berk.* }	*	*	*	...	*	...	*	
AMPHIBIA.								
Rana temporaria	*	*	*	...	*	...	*	
Bufo Calamita	...	...	...	...	...	...	...	*
Triton palustris? [a]	*							
Lissotriton punctatus	*	...	*	...	...	*		
—— palmipes?	...	...	...	...	...	*		
PISCES.								
Perca fluviatilis	*	...	*	...	...	*	*	
Labrax Lupus	*	...	*	...	...	*	*	
Trachinus Vipera	...	*	*	...	...	...	*	
Mullus Surmuletus [b]								
Trigla Pini	*	...	*	...	*	...	*	
—— lineata	*	...	*	...	*	...	*	
—— Hirundo	*	...	*	...	*	...	*	
—— Lyra	...	...	...	...	*	...	*	
—— Gurnardus... } One —— Cuculus...... } species.	*	...	*	...	*	...	*	
—— Pœciloptera	...	...	...	...	...	...	*	
Cottus Scorpius	*	...	*	...	*	...	*	
——— Bubalis	*	...	*	...	*	...	*	
Aspidophorus cataphractus	*	...	*	...	*	...	*	
Gasterosteus aculeatus	*	...	*	...	...	*	*	
—— pungitius	*	...	...	*				
—— Spinachia	*	...	*	...	*	...	*	
Sciæna Aquila	...	...	...	...	...	...	...	*

[a] See preceding remarks on.

[b] Given on authority of Dr. Brown's catalogue, in which no locality is named.

PISCES.	North.		East.		West.		South.	
	Belfast.	Elsewhere in North.	Dublin.	Elsewhere in East.	West of Connaught.	Elsewhere in West.	Youghal.	Elsewhere in South.
Pagellus Centrodontus	*	...	*	...	*	...	*	
Scomber Scomber	*	...	*	...	*	...	*	
—— maculatus	...	...	...	...	*			
Thynnus vulgaris	...	...	*					
—— Pelamys	...	...	...	...	...	...	...	*
Caranx Trachurus	*	...	*	...	*	...	*	
Zeus Faber	*	...	*	...	*	...	*	
Lampris Luna	...	*	...	...	...	...	...	*
Mugil Chelo	*	...	*	...	*?	...	*	
—— Capito	*							
Atherina Presbyter	*	...	*	...	...	...	*	
Blennius Gattorugine	*							
—— Yarrellii, *Val.* (B. palmicornis, *Yarr. and Jenyns' Works*)	*							
—— Pholis	*	...	*	...	*	...	*	
Murænoides guttata	*	...	*	...	*	...	*	
Zoarces viviparus	*							
Anarrhicas Lupus	*	...	*	...	*?			
Gobius niger, *Cuv.*	...	...	...	...	*	...	*	
—— Britannicus, *Thomp.* (G. niger, *recent Brit. authors*)	...	...	*?	...	...	...	*	
Gobius Ruthensparii (G. bipunctatus, *Yarr.*)	*	...	...	...	*			
—— minutus	*	...	...	...	*	...	*	
—— gracilis	*	...	...	...	...	...	*	
—— unipunctatus	*	...	...	...	...	...	*	
Callionymus Lyra	*	...	*	...	...	...	*	
—— Dracunculus	*	...	*	...	*	...	*	
Lophius Piscatorius	*	...	*	...	*	...	*	
Labrus variabilis (L. maculatus, *Bl.*) —— lineatus } one.	*	...	*	...	*	...	*	
—— variegatus	*	...	*	...	*	...	*	
—— trimaculatus	...	*						
Crenilabrus Tinca —— Cornubicus —— gibbus } one.	*	...	*	...	*	...	*	
—— rupestris	*	...	...	...	*			
—— pusillus	...	...	...	...	...	...	*	
—— exoletus	...	*	...	...	*			
Gobio fluviatilis	*	...	*	...	...	*		
Tinca vulgaris[a]								
Abramis Brama	*	...	...	...	...	*		
—— Buggenhagii	*							
Leuciscus Erythrophthalmus	*	...	*	...	*?	...	*	
Cobitis barbatula	...	*	*	...	...	*		*
Esox Lucius	*	...	*	...	...	*	...	*
Belone vulgaris	*	...	*	...	*	...	*	
Scomberesox Saurus	*	...	*					
Exocœtus exiliens?	...	...	...	...	...	...	*	
Silurus glanis?[b]	...	...	...	...	...	*		

[a] Possibly introduced—see preceding remarks on.

[b] See preceding remarks on.

PISCES.	North.		East.		West.		South.	
	Belfast.	Elsewhere in North.	Dublin.	Elsewhere in East.	West of Connaught.	Elsewhere in West.	Youghal.	Elsewhere in South.
Salmo Salar[a]	*	...	*	....	*	...	*	
—— Eriox	*							
—— Trutta	*	...	*	....	*	...	*	
—— Fario	*	...	*	....	...	*	*	
—— ferox	*	...	...	....	...	*		
—— Umbla, *L.* } one. —— Salvelinus, *Don.* }	*	*	*	...	...	*	...	*
Osmerus Eperlanus	*							
Coregonus Pollan	*	...	...	....	...	*		
Clupea Harengus	*	...	*	...	*	...	*	
—— Sprattus	*	...	*	...	*	...	*	
—— Pilchardus	*	...	*	....	*	...	*	
Alosa Finta	...	*	...	....	*	...	*	
—— communis	...	*						
Gadus Morrhua	*	...	*	....	*	...	*	
—— Callarias	*	...	...	...	...	...	*	
—— Æglefinus	*	...	*	...	*	...	*	
—— luscus	*	...	*	....	*	...	*	
—— minutus	*	...	...	....	*	...	*	
Merlangus vulgaris	*	...	*	...	*	...	*	
—— Pollachius	*	...	*	...	*	...	*	
—— Carbonarius	*	...	*	...	*	...	*	
Merlucius vulgaris	*	...	*	....	*	...	*	
Lota Molva	*	...	*	...	*	...	*	
Motella tricirrhata	*	...	...	...	*	...	*	
—— Mustela	*	...	*	....	*	...	*	
Brosmus vulgaris ?	*							
Phycis furcatus	*							
Raniceps trifurcatus	*							
Couchia minor	...	*						
Platessa vulgaris	*	...	*	...	*	...	*	
—— Flesus	*	...	*	...	*	...	*	
—— Limanda	*	...	*	...	*	...	*	
—— microcephala	*	...	*	...	*	...	*	
—— Pola	...	*	*					
Hippoglossus vulgaris	*	...	*	...	*	...	*	
Pleuronectes maximus	*	...	*	...	*	...	*	
—— Rhombus	*	...	*	...	*	...	*	
—— punctatus	*							
—— hirtus	...	*						
—— Megastoma	*	...	*	...	...	...	*	
Solea vulgaris	*	...	*	...	*	...	*	
—— Lingula	*	...	*	...	*	...	*	
—— variegata	*							
Lepadogaster Cornubiensis	...	*	...	....	*	...	...	*
—— bimaculatus	*	...	*	...	*			
—— cephalus	...	...	...	...	*			
Cyclopterus Lumpus	*	...	*	...	*	...	*	
Liparis vulgaris?[b]	*							
—— Montagui	*	...	...	...	*	...	*	
Anguilla acutirostris	*	...	*	...	*	...	*	
—— latirostris	*	...	...	...	...	*		

[a] *S. Salmulus*, Young.

[b] See preceding remarks on.

PISCES.	North. Belfast.	North. Elsewhere in North.	East. Dublin.	East. Elsewhere in East.	West. West of Connaught.	West. Elsewhere in West.	South. Youghal.	South. Elsewhere in South.
Anguilla mediorostris ?[a] ...	*							
Conger vulgaris	*	...	*	...	*	...	*	
Leptocephalus Morrissii	*	...	...	...	*	...	*	
Ophidium imberbe	*							
Echiodon Drummondii	*							
Ammodytes Tobianus	...	*						
—— Lancea	*	...	*	...	*	...	*	
Syngnathus Acus	*	...	*	...	*	...	*	
—— Typhle	*	...	...	...	...	...	*	
—— æquoreus	*	...	...	...	*	...	*	
—— anguineus	*	...	...	...	*	...	*	
—— lumbriciformis	*	...	*	...	*	...	*	
Hippocampus brevirostris ? .	*	...	*	...	...	...	*	
Tetrodon stellatus	...	...	...	...	...	...	...	*
Orthagoriscus Mola	*	...	*	...	*	...	*	
Acipenser Sturio ?	*	...	*	...	...	...	*	
Scyllium Canicula	*	...	*	...	*	...	*	
—— stellaris	*							
Pristiurus melanostomus ...	...	*						
Carcharias Vulpes ?	*							
—— glaucus	...	...	*	...	*	...	*	
Lamna Cornubica } One ?	...	...	*	...	*	...	*	
—— Monensis ... } One ?	*							
Galeus vulgaris	*	...	*	...	*	...	*	
Mustela lævis	*	...	...	...	...	...	*	
Selachus maximus	...	*	...	...	*	...	*?	
Spinax Acanthias	*	...	*	...	*	...	*	
Squatina Angelus	*	...	*	...	...	...	...	*
Torpedo Walshii	...	...	*	...	...	...	...	*
Raia Batis	*	...	*	...	*?	...	*?	
—— Oxyrhynchus	...	...	...	...	...	...	...	*
—— chagrinea	...	*						
—— maculata	*	...	*	...	...	...	*	
—— clavata	*	...	*	...	*	...	*	
—— radula	*	...	*					
Trygon Pastinaca	*?	...	...	...	...	...	...	*
Cephaloptera Giorna	...	...	...	...	...	...	...	*
Petromyzon marinus	*	...	...	...	...	*		
—— fluviatilis	*	...	*	...	...	...	*	
—— Planeri	...	*	*	...	...	*	*	
Ammocoetes branchialis ...	*	...	*	...	...	...	*	
Myxine glutinosa	*							

[a] See preceding remarks on.

Report of Experiments on the Physiology of the Lungs and Air-tubes. By Charles J. B. Williams, M.D., F.R.S.

When at the request of the Medical Section of the British Association, I undertook three years since to investigate experimentally several doubtful points respecting the properties and offices of parts of the respiratory apparatus in the higher classes of animals, I hoped to be able to include in the inquiry the chemical process of respiration, and the vital effects of its interruption. Professional engagements having obliged me to relinquish these points, I have restricted my attention to others more immediately bearing on practical medicine. The chief of these are the contractility and sensibility of the air-tubes and lungs.

It has long been a matter of controversy whether the lungs and air-tubes are more than passive in the motions of respiration; whether they possess any self-contracting or expanding power, independent of the muscles which affect the capacity of the chest. Different writers, both ancient and modern, have maintained opposite opinions. Laennec, after Sennert, Bremond and others, attributed to the lungs both a self-contractile and self-expansive power, in addition to their mechanical or elastic properties. Haller, on the other hand, was led by experiment to deny that any independent vital motions are exhibited by the lungs of animals, corresponding with those of respiration; and Müller has confirmed these negative results. Within the last few years certain writers in this country and in France*, have denied altogether the muscular contractility of any part of the air-tubes below the larynx.

These negative observations are in opposition to the generally-received opinion, derived chiefly from the anatomical researches of Reisseissen, that the circular fibres of the air-tubes, from the trachea to their terminations, are muscular. Very few attempts have been made to solve this problem by experiment. Varnier and Wedemeyer only succeeded in exciting partial contractions in the smaller bronchi; but after all their results, Müller concludes that "it is remarkable that there exists at present no direct proof of the contractility of the muscular fibres of the trachea and its branches†."

I need scarcely remark, that this subject is by no means one of merely speculative interest. Much of the pathology and

* MM. Trousseau and Belloc, Dr. Geo. Budd, &c.

† Elements of Physiology, translated by Baly.

treatment of various diseases of the respiratory organs, especially asthma, is at present founded on the supposition of a muscular contractility of the air-tubes, the very existence of which is stated by one of the most eminent of modern physiologists to be little more than assumed. The chief objects of the following experiments were to test the existence of muscular irritability in the air-tubes; and if such were present, to determine its character, and the circumstances or influences which could affect or disturb it. The experiments were performed at the London University College, and in several of them I was kindly assisted by Professor Sharpey, Mr. James Blake, Dr. Davison, and several of my pupils, especially Messrs. Blomfield, Carlill, Parkes and Jos. King.

In most of the experiments I made use of Poiseuille's hæmadynamometer, which is a tube bent like an inverted siphon, containing a coloured fluid; the short limb of this tube, furnished with stop-cocks, being adapted to the windpipe or one of its branches, the column of fluid within would be readily moved by any contraction of the air-tubes or lungs, causing pressure on the air in it: and the rise or fall of this fluid was measured by a scale divided into inches and tenths.

1. A dog was killed by pithing. The chest being immediately opened, the lungs collapsed completely. They were taken out with a part of the trachea, which was then tied to the brass tube of the hæmadynamometer (or as I shall call it, the *dynameter*); on completing the communication by turning the stop-cock, the fluid in the tube oscillated several times to the amount of about one fourth of an inch. On passing a galvanic current, from a trough of thirty three-inch plates, from the margin of the lungs to the brass tube in the trachea, the fluid rose quickly, but gradually, nearly two inches; it sunk speedily on breaking contact; again rose on repeating it; but fell slowly when the contact was continued for some seconds. When the current was passed only through a single lobe, the rise was still distinct, amounting to three or four tenths of an inch. The rise was repeatedly produced, but to a diminishing extent, and after two or three minutes the effect seemed to be exhausted.

2. The preceding experiment was repeated with eight dogs of various sizes, with similar results. The rise of the fluid column caused by galvanising the whole lung amounted at first to from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches, but afterwards gradually diminished. If the current was passed continuously for some length of time, the fluid in the tube fell, and could not be raised by the galvanism for a minute or two after. It was found also that inflating the lungs impaired the effect of the current. On repeating the

experiments further, it was found that the irritability was only exhausted for a time; and on waiting two or three minutes between each application of the galvanism, the liquid was raised again and again for upwards of an hour; at first to the extent of one or two inches, but afterwards to a gradually diminishing extent, until all effect ceased. So, too, although no effect ensued immediately after inflating the lung, yet on waiting a minute or two the contraction took place, only diminished in degree by the compressed state of the air, which required more contractile force to move it. The fall on interrupting the current was pretty rapid, the fluid recovering its level in from ten to twenty seconds.

3. Several trials were made to compare the contractility of the smaller and the larger bronchial tubes respectively. When the galvanism was passed along only the margins of the lobes, scarcely any contraction ensued. When passed from the margin to the middle of the lobes the column rose two or three tenths and soon subsided. When passed across a lobe, at right angles with the chief tubes, the rise was from two to four tenths. But the greatest amount of contraction was caused by passing the current from the margins of the lobes to the larger tubes, or across the direction of these tubes, especially near the bifurcation of the trachea. The rise produced by galvanising these portions could be also renewed at intervals for a period much longer than in other parts.

4. The preceding experiments were all made on the lungs removed from the body immediately after death. I tried to obtain the same results with the lungs in the body; but it was not easy to galvanise the lungs without affecting the muscles of the chest, the contractions of which might interfere with the results. The expedient adopted was, immediately on the death of the animal to adapt the dynameter to the trachea; then to open the chest and break back the ribs, and having separated the lungs, to pass between them and the walls of the chest a piece of oiled cloth, and then to apply the galvanic wires to different parts of the lungs. This experiment gave less distinct results than when the lungs were removed from the body. It was repeated five times; but it will be sufficient to describe one instance in which the galvanism was tried on the par vagum as well as on the lungs themselves. A large dog was pithed, and the dynameter adapted to the trachea. On opening the chest, the collapse of the lungs caused the fluid to rise three inches. The vagi being exposed in the neck, one was pinched; it caused no effect on the dynameter. The other vagus was then galvanised across and along a portion of it; no effect followed in the bronchial

tubes, but the œsophagus was strongly convulsed. The nerve was then separated and the galvanism passed through it to the base of the lung; this raised the dynameter only a tenth. On passing the current from the base of the lungs to the trachea the column rose more than an inch, sinking again rapidly on the withdrawal of the galvanism.

5. In all the preceding experiments the animals were killed by pithing: other modes of death were afterwards tried. A rabbit was killed by a blow on the back of the neck. The lungs and trachea being cut out, moderately inflated and galvanised, little effect was produced in the first ten minutes, but the column had gradually sunk about three tenths of an inch, after this the galvanism repeatedly raised it two tenths.

6. A large dog was bled to death by dividing the jugular veins. Death was preceded by very deep and rare breathing; the heart beat a few pulses after respiration and sensibility had ceased. On adapting the dynameter to the trachea, the column was stationary; on opening the abdomen it sunk half an inch. On opening the chest it rose five inches. After taking the lungs out of the body, galvanism failed to raise the column; but this failure probably arose from the tube being obstructed with viscid mucus; for on applying the wires to the bifurcation of the trachea the tubes were seen to contract distinctly. This suggested another mode of observation which had been distrusted before, as liable to error. The lungs were cut by sharp scissors at right angles to the chief air-tubes; the open sections being galvanised contracted to half, and in some instances to less than half their former diameter. To ensure accuracy, the gaping ends, as soon as cut, were measured by compasses or tubes of similar size. The contraction was most distinct in the middle-sized tubes, and those of the size of a crow-quill. One of these closed completely. These results were obtained for half an hour after death, and long after the heart had lost its irritability.

7. A large greyhound was killed by pithing. The lungs being removed, one lobe was tried by galvanism and the dynameter, with the usual results. A large bronchus of another lobe was then cut open longitudinally, laid flat and then galvanised. It became hollow and contracted a third, and at one part half its diameter. The divided ends of other bronchi also contracted to less than half. In one instance, when the interior of a large bronchus was galvanised, bloody mucus was expelled from one of its branches across which the current passed.

8. A bullock's lung was experimented on about twenty minutes after death, which was caused as usual by a blow on the

head and dividing the vessels of the neck. The bronchi were full of frothy mucus, and on touching any of them with the galvanic wires, this froth was exuded from them. Their measured size also shrunk under the same influence.

9. The same results were obtained with the lungs of a calf, half an hour after death (by bleeding and pithing). A small lobe of the lung when galvanised raised the dynameter three tenths.

10. Two years ago I observed in the lungs of a horse just killed by *knacking*, that the divided ends of the bronchi slowly contracted on being irritated with a scalpel; but as no measurement was used, and as those which were not thus irritated also contracted, only more slowly, I did not then consider the result conclusive. It may, however, now be arranged among other facts of the same kind.

11. In many instances which I need not now detail, I tried to excite the contraction of the air-tubes by chemical irritants, such as salt and diluted ammonia. I succeeded with the divided ends of the tubes; but with the dynameter it was more difficult, from the difficulty of introducing the irritant without mechanically affecting the column, and also from the irritant causing the formation of mucous viscid froth, which obstructed the tubes. The following was the most successful of these attempts.

12. A dog was pithed and the lungs exposed by breaking back the ribs. To the trachea was tied a tube with two branches furnished with stop-cocks. One branch communicated with the dynameter; through the other the lungs were to be inflated to give the tubes their full diameter. The irritating fluid was poured into the tube of the dynameter in quantity sufficient that some might drop into the trachea on blowing into the upper end of the tube. The lungs being moderately inflated, the stop-cock of the dynameter was turned, when the column rose three inches. The column was then depressed by blowing with the mouth till some dropped into the windpipe. On withdrawing the mouth the column was driven up three tenths above its former level, and slowly rose two tenths more. This rise could only be ascribed to the contraction of the tubes excited by the irritating liquid in them. By changing the position of the lung, several sudden starts of one or two tenths repeatedly occurred, probably caused by the irritating fluid coming in contact with more tubes. But all these movements were much impeded by the viscid froth which collected in the bronchi. The lungs being suffered to collapse, the column sank to a level. After a while it sunk further two inches below the level; being

probably thus drawn down by the re-expansion of the cartilaginous rings of the tubes, now set free by the relaxation of their contractile fibres. On cutting into the lung the trachea and bronchi were found unusually open, and filled with tenacious froth. In another instance in which this experiment was repeated, the rise after the injection of diluted ammonia amounted to $1\frac{1}{2}$ inch.

13. The experiment was repeated with saturated solution of common salt, with similar results.

14. The following experiment illustrates several of the same points; and further shows the character of the sensibility in different parts of the air-passages. Subject, a large Newfoundland dog. The trachea was exposed and divided below the cricoid cartilage. It was then held out by a hook. On being irritated by a scalpel, the membranous portion gradually contracted until the ends of the cartilaginous rings met. The contraction was somewhat increased by galvanism. The application of salt caused no further effect. None of these irritations excited cough or sign of uneasiness; but on passing the finger upwards to the larynx, violent expiratory efforts were excited, and the glottis very forcibly closed on the finger. The expiratory efforts forced a little bloody mucus from the trachea. A scalpel was introduced into the trachea as far as its bifurcation, and scraped against the membrane. No cough followed for some time; but on repeating the experiment about a minute after, cough ensued, and increased on subsequent trials. The salt applied caused a secretion of bloody mucus. The blood-vessels in the upper part of the chest were now cut into, when the rare deep inspirations preceding death by hæmorrhage succeeded. The heart continued to beat several seconds after the cessation of respiration. The bronchi exhibited full indications of contractility on the application of galvanism, or of salt, or ammonia. The upper part of the trachea, which had during life been irritated with salt and galvanism, was now found quite expanded, the portions lower down were half-expanded. Both contracted slightly on being galvanised, and completely on dividing their cartilaginous rings.

Having satisfactorily proved the existence of irritable contractility in the air-tubes, I next proceeded to try how this would be influenced by various medicinal agents which we are in the habit of using in various diseases of the organs of respiration.

15. A rabbit was poisoned by dropping some strong hydrocyanic acid into its mouth. In thirty seconds it was seized with convulsive and gasping breathing, and opisthotonic spasms, and died in ten seconds more. Galvanism produced no results with

the dynameter for the first five minutes; but after this it took effect, and raised the column two tenths; and in a quarter of an hour four tenths. These effects gradually diminished, and ceased in half an hour.

16. About ten grains of extract of belladonna*, mixed with water, were injected into the jugular vein of a rabbit. In fifteen seconds, gasping with slight convulsions, and death in less than a minute. On opening the abdomen the heart was seen through the diaphragm acting quickly. The dynameter being adapted to the trachea, the chest was opened, when the column immediately rose two inches, and slowly an inch more, when it remained stationary. Galvanism produced no effect for several minutes, and then a scarcely perceptible rise, which could not be re-induced, although the experiment was continued an hour.

17. A dog was poisoned by mouth with hydrocyanic acid. He fell down howling in a minute and a half, and ceased to breathe in about half a minute more. Heart beat strongly when the chest was opened. Galvanism raised the column of the dynameter two inches, and a similar but decreasing effect was obtained at times for half an hour. The same differences were observed in the contractility of different parts, as after death by pithing. The cut ends of the tubes continued to contract on being galvanised half an hour after death.

18. About twenty drops of strong hydrocyanic acid were injected into the carotid artery of an ass about six months old. It immediately caused the breathing to become very deep and rare; but the effect passing off in about ten minutes, nearly a drachm more was injected. The deep convulsive breathing returned, with tetanic rigidity of the trunk and loud groaning. The breathing became very rare, whilst the heart beat violently with a double second sound. Death ensued about three minutes after the second injection. A small lobe of the lung when galvanised repeatedly raised the column three tenths. Sections of tubes in other parts contracted distinctly on being galvanised, but to a less extent than in the dog. Contractile motion was distinctly seen on cutting a cartilaginous ring of the trachea, and then galvanising the membranous portion at the back.

19. About ten grains of extract of belladonna mixed with water, were injected into the right jugular vein of a large dog. Pupils began to dilate in fifteen seconds, and breathing more and more deep and laborious, accompanied with convulsive starts and howling. The breathing ceased and the eye became insensible two minutes after the injection. The integuments of

* This and other extracts used were obtained from Mr. Squire, Chemist to the Queen.

the chest being then divided, some dark blood flowed in jets from the cut vessels ; the animal then made six or seven deep gasps, during which the heart beat more strongly, and the eye slightly winked on being touched. This partial restoration was probably caused by the bleeding. On taking out the lungs scarcely a trace of contractility could be detected in them by the dynameter, and the cut ends of the tubes shrunk but little on being galvanised. The trachea was quite relaxed, and scarcely any approximation of the cartilages was produced by galvanism. The arteries also were less contracted than usual.

20. About thirty grains of extract of stramonium were injected into the cellular tissue of the neck of a dog. The breathing soon became very quick, laborious, and occasionally stertorous. Lower extremities very weak and dragged, as if paralysed. Pupil extremely dilated ; but the sensibility of the eye and consciousness of sounds remained till near death, which took place twenty-five minutes after the injection. The heart was found motionless and unirritable, its right cavities and the veins much gorged with blood ; left cavities and arteries empty. On cutting and galvanising the bronchi, very little contraction was perceived, and none with the dynameter. Œsophagus and intestines still irritable.

21. Two grains of nitrate of strychnia, dissolved, were injected into the carotid of a large dog. In less than four seconds tetanic convulsions, which continued a minute. The eye became insensible in half a minute. On opening the chest the heart was found motionless and unirritable ; right cavities and veins enormously distended. Lungs being taken out and galvanized, at first raised the dynameter two tenths, but not afterwards. Voluntary muscles relaxed after death, and were less irritable than usual.

22. A solution of four grains of nitrate of strychnia was injected into the jugular vein of a donkey two months old. In fifteen seconds spasms and tetanic stiffness. Eye soon ceased to wink on being touched. Spasms of neck and back continued for more than a minute On opening the chest the heart was still beating, the veins and right side much distended. The air-tubes gave no sign of contractility with galvanism, although the experiment was continued for some time.

23. Wishing to compare the contractility of the bronchi with that of the arteries, I made the following experiment. Immediately after the death of the subject of the preceding experiment, ligatures were applied to the top of the descending aorta and to the left common iliac, and a dynameter to the right common iliac, some carbonate of soda and water being first injected

to prevent the blood from coagulating. The aorta was then galvanised, and the column immediately rose gradually two inches. On removing the wires, it still rose a few seconds, and then sunk progressively. After it had sunk two inches, the galvanism again raised it two tenths, but no more. This was about twenty-five minutes after death. The auricles continued to be excitable by galvanism more than half an hour after death, the contraction of one auricle being followed by that of the other. In this and another donkey, I had proved that the arteries contracted during life on the application of the galvanic, as well as of chemical and mechanical stimuli.

24. Some tincture of *Lobelia eflata*, much concentrated by evaporation, was injected into the jugular vein of a dog. There were symptoms of uneasiness for a few minutes, but no further effect. A fluid extract obtained by evaporating ℥iss. solution of bimeconate of morphia (Squire) was then injected. In twelve seconds, peculiar convulsive starts and some general tremor, with laborious breathing, followed by death in about a minute and a half. Heart was beating when the chest was opened. Single lobes of the lungs being galvanised raised the dynameter column slightly, not more than a tenth. On cutting the lung, the sections contracted more distinctly, but much less so than in other cases. Trachea expanded.

25. About half a drachm of extract of conium mixed with water was injected into the external jugular vein of a dog. In twelve seconds the breathing became very quick and laborious, and in a minute the animal was dead. Bronchi not contractile as tested by the dynameter, and less than usual on galvanising cut portions. The trachea was already contracted so much that the ends of the cartilaginous rings were in contact. The heart was still irritable.

I trust that many of the results of the preceding experiments are sufficiently evident without further comment.

Almost all of them prove that the air-tubes are endowed with irritable contractility, excitable by electric, chemical, and mechanical stimuli, and they possess also tonic contractility (10, 25).

The contractility is manifest in all portions of the air-tubes (3, 6, 7, 12, &c.). In the trachea and larger bronchi it is antagonised by the elasticity of the cartilaginous rings (12, 14). It does not appear to exist in the vesicular terminations of the air-tubes (3).

This contractility resembles that of the intestines or arteries more than that of voluntary muscles, the œsophagus, or heart, the contractions and relaxations being more gradual than those

of the latter, but less tardy than those of the former. (1, 2, 17, 23, &c.)

The irritability of the bronchial muscles is soon exhausted by the action of a stimulus (1, 2, 5, 12, &c.); and may in some degree be restored by rest, even when the lung is removed from the body for an hour or more (2, 3, 6). But when the stimulation is long continued, as by intense irritation of the mucous membrane during life, the irritability is not restored by rest, and the tonic contractility is also impaired (14).

The contractility of the air-tubes seems to be much influenced by the mode of death; having been for a time suspended after death by a blow on the back of the neck (5), and in one instance after death by pithing, and hæmorrhage. Inflation of the lung also in some way suspends it for a while (2).

Several vegetable poisons impair or destroy this contractility. Extracts of stramonium and belladonna produced this effect most completely (16, 19, 20). (Their superior efficacy in spasmodic asthma has been long known.) Strychnia, conium, and morphia also impair this property considerably (21, 22, 24, 25). Hydrocyanic acid, on the other hand, does not in any considerable degree impair it (15, 17, 18).

These poisons and different modes of death do not act on the irritability of the bronchial tubes in the same degree as they do on that of the heart and other contractile tissues, (22, 23, 24, 25,) and they do not seem to act always equally on the irritable and on the tonic contractility of these tubes (25).

The bronchial fibres seem to be excited more by direct stimulation than by any influence conveyed through the nerves of the lungs; for mechanical and galvanic irritation of the vagi had no effect on them; and passing a current through the nerves to the lungs caused much less contraction than passing it through the trachea (4).

I am well aware that these, and many other subjects connected with them, deserve a fuller investigation, and I have to regret that my engagements have prevented me from prosecuting them further. Such as they are I submit them to the consideration of the Section without dwelling on their practical bearings.

Charles J. B. Williams, M.D., F.R.S.,
Professor of the Principles and Practice of Medicine, and Physician to the Hospital, London University College.

Holles Street, Cavendish Square,
Sept. 15th, 1840.

Report of the Committee appointed to try Experiments on the Preservation of Animal and Vegetable Substances. Drawn up by The Rev. J. S. Henslow, *F.L.S., Professor of Botany in the University of Cambridge.*

The Committee have hitherto directed their attention entirely to the investigation of the preserving properties of certain materials when applied separately, either in saturated solutions, or in different degrees of concentration.

A set of glass jars, of uniform dimensions (6 inches by $1\frac{1}{2}$), was procured, and saturated solutions of the substances to be tried were prepared. Similar solutions were also diluted with an equal quantity of water, and with double the quantity of water, and separate preparations were made of animal and vegetable substances to the amount of 178. These were left in the Museum of the Botanic Garden at Cambridge, and have been inspected at intervals of one and two years. It is intended that all should remain where they now stand, whether the results may prove satisfactory or not; as, possibly, some facts may be elicited worth noticing, respecting the different manner in which organized substances are decomposed when placed in a variety of mixtures which do not preserve them.

The next step which the Committee propose taking, will be to mix those solutions which seem to them most likely to succeed, in various proportions; and to prepare a fresh set of objects in these mixtures, which will be placed with the former. This, indeed, ought to have been done some months ago, but circumstances have prevented the Committee from carrying this part of their plan into effect. No very satisfactory conclusions can be expected to result from these experiments until they shall have stood the test of a greater length of time than has yet elapsed since they were commenced. An account of the results hitherto obtained will be of service in directing the researches of any who may be disposed to follow up the inquiry, and the Committee will be glad to receive the suggestions or aid of any members of the Section who may be disposed to cooperate with them.

1*st. Results obtained with Animal Substances.*—Three salts of potash, the sub-carbonate, the bi-carbonate, and the arseniate, have hitherto yielded the most satisfactory results, and of these more especially the sub-carbonate. Although the bicarbonate has preserved the objects immersed in it, the liquid has become clouded with flocculent matter. A similar formation of flocculent matter occurs in some of the other solutions, but has not yet been minutely examined. These three salts are effective in each of the three states of concentration employed, but perhaps the effect is best where the solution is half of the saturated solution and half of water.

The next best to these three, are the sulphate of zinc, the muriate of magnesia, and arsenious acid.

The following also possess tolerably fair preserving properties, but are by no means so good as those already mentioned. They may be recommended in cases of emergency, as temporary expedients, and some of them will probably prove more efficient when used in combination with others, than when employed singly: sulphate of magnesia, sulphate of potash and alumina, (common alum,) sulphate of zinc, muriate of ammonia, sulphate of potash. It is well known that corrosive sublimate is a perfect preservative of animal substances, but this salt renders the flesh so very hard, that singly it is unsuited to the purposes of natural history. Added in small proportions to other solutions, which render the objects too soft, it will probably be found of essential service; as well also in preventing the formation of the flocculent matter which occurs in several of them.

Prepared naphtha, in the proportion of one part naphtha to seven of water, produces a favourable result, but when used more highly concentrated the specimens are rendered tough. The rapid evaporation of this substance is an objection to its use.

The effects produced by oxalic acid, and acetic acid, are peculiar; they seem to have decomposed the skin and cellular membrane of two small fish immersed in them, but to have left the muscle untouched. The consequence has been that these animals have fallen to pieces, but the separate fragments are well preserved, more especially in the acetic acid.

A few drops of kreosote added to water preserves the objects, but they become stained of a dark brown. The following substances appear to be wholly unfit for the purpose, and no further trial need be made with them: carb. ammonia, chloride of potash, muriate of barytes, muriate of lime, nitrate of ammonia, nitrate of strontian, nitrate of barytes, nitrate of soda, nitrate of ammonia and magnesia, phosphate of soda, sulphate of soda, sulphate of potash, sulphate of iron, sulphate of copper, rough pyroligneous acid.

2nd. Results obtained with Vegetable Substances.—The success obtained with vegetable substances has been very slight. Specimens were immersed in each solution, as in the case of the animal substances. None of the salts seem likely to turn out favourably in simple solution, unless it may be the sub-carbonate and bi-carbonate of potash. In naphtha and acetic acid the specimens are preserved, but in the latter they lose their colour and assume a reddish tinge.

P.S. It does not appear from the memoranda that the carbonates of soda are among the list of substances tried; but I have found that the preserving properties of the common soda of the shops are decidedly good on animal substances.

J. S. HENSLOW.

PROVISIONAL REPORTS, AND NOTICES OF PROGRESS IN SPECIAL RESEARCHES ENTRUSTED TO COMMITTEES AND INDIVIDUALS.

Mathematics and Physics.

Statement by G. B. Airy, Esq., *Astron. Royal, relating to the progress of the Reductions of the Greenwich Lunar and Planetary Observations, undertaken at the recommendation of the British Association; and to the state of the Funds appropriated to these works.*

A resolution of the General Committee of the British Association, recommending to the Government the reduction of all the observations of the Planets made at Greenwich from the time of Bradley, was passed at Cambridge on June 28, 1833, and a deputation was appointed to wait on Lord Althorp, in order to present this recommendation, and to request that the sum of 500*l.* should be placed in my hands for these reductions. The sum named was fixed on wholly at random, and without any sort of accurate estimate, of which the operations did not seem to admit.

Lord Althorp's answer assenting to the grant was dated July 25, 1833. It was understood verbally from his Lordship's private secretary (Mr. Drummond), that more money would be granted if required.

The whole sum of 500*l.* has been advanced to me by the following payments.

1836—Jan. 8 . . .	£122	17	9
1837—May 27 . . .	179	2	9
1838—Feb. 24 . . .	197	19	6
Total . .	£500	0	0

The last payment is subsequent to the later arrangement with regard to lunar reductions, of which I now proceed to speak.

In the Meeting of the Association at Liverpool in 1837, the General Committee recommended that the Observations of the Moon should be reduced, and appointed a deputation to wait on Mr. Spring Rice, and to convey this recommendation. The

deputation accordingly attended at the Exchequer in the winter of that year, and made the application, naming the sum of 2000*l.* as necessary, but stating in the formal memorial that the expense might probably exceed 2000*l.* And on December 26 of the same year, in writing to Mr. Spring Rice on this matter, I recommended that the accounts for planetary reductions and lunar reductions should be incorporated, as in pursuing the work in the most advantageous way, it was wholly impossible to keep the operations separate.

The Lords of the Treasury assented to this application, and directed that 600*l.* should be advanced per annum, till the 2000*l.* should be expended.

In the applications made by me to the Lords of the Treasury on April 13, 1839, and April 18, 1840, I stated fully that the money last granted (for the lunar reductions) had been employed in part on the planetary reductions.

The advances made to me from the Treasury are the following:—

1838—June 13 . . .	£600	0	0
1839—May 31 . . .	600	0	0
1840—April 27 . . .	600	0	0
Total . .	£1800	0	0
Leaving still payable to me from the original grant .	200	0	0
And on Sept. 4, 1840, I had in hand about . . .	563	0	0
I have, therefore, at my command	763	0	0

This sum may be expected to last a short time beyond the next meeting of the Association; but it would not, in my opinion, be prudent to defer proceedings for increasing the sum till that time.

The state of the reductions is nearly as follows:—

Planets.

The transits and right ascensions of all the planets are nearly all completed in duplicate, compared, examined by differences, and in other ways.

The polar distances are entirely reduced in duplicate, compared, examined, &c. for all the planets, except an inconsiderable part of the observations of Uranus (probably finished by

this time), and the observations of the small planets, for which the distance necessary for the parallaxes is wanting.

The computation of geocentric longitude and latitude from Æ and NPD is finished in duplicate for Mercury, Venus and Mars, examined and compared. Jupiter is advanced (probably now finished), and Saturn has been commenced (probably now far advanced).

The computation of the Tabular Heliocentric places of all the planets, except the small ones, is finished in duplicate and examined.

The computation of the Tabular Geocentric places is finished for all the large planets, except the application of aberration to Saturn and Uranus, and a few observations of Jupiter.

The reduced observed places have been confronted with the reduced tabular places for Mercury and Mars, and thoroughly examined by myself; and these are, in all important respects, ready for printing. Those for Venus have also been computed, but not yet thoroughly examined by me.

The whole of this department will, in no long time, be ready for press. The only new work to be done upon it is the calculation of the co-efficients of tellurian and planetary heliocentric errors, which must be conceived to form the geocentric errors.

Lunar Observations.

The whole of the imperfect transits are completed; and this has been a very laborious operation.

The apparent Æ of the stars for the clock-errors are formed, and are ready for application to the investigation of the moon's right ascension, but are not yet applied.

No other work is yet done for the lunar observations, though the books, &c. are prepared for many parts of the work.

G. B. Airy.

To the Committee of the Physical and Mathematical Section of the British Association.

The Report of the *Committee on the Form of Vessels* was read to the Meeting; but in consequence of the extensive tables and drawings required for its illustration, it has not yet been completed for publication.

The *Committee appointed to superintend the extension of the Royal Astronomical Society's Catalogue of Stars*, report—

That the work is in considerable progress, and that it will probably be completed before the next meeting of the British Association in 1841. They further report, that 360*l.* have been

already paid for computations, and about 70*l.* for printing and other expenses, making a total of about 430*l.* out of the original grant of 500*l.* As this balance of 70*l.* will not be sufficient to complete the work, the Committee request that it may be extended to 150*l.*, which, they hope, will meet every expense.

THE *Committee appointed to superintend the reduction of the stars in the Histoire Céleste*, report—

That about 33,000 stars have been already reduced, the cost of which has been 412*l.*, exclusive of about 52*l.* for printing skeleton forms for the use of the computer. They further report, that there are about 16,000 more stars to be reduced, the cost of which will be about 200*l.* more. As the original grant will not cover the whole of this expense, (there being only about 35*l.* remaining out of that grant,) the Committee suggest the propriety of extending the grant, for the ensuing year, to the 200*l.* above mentioned, which, they trust, will complete the work.

FRANCIS BAILY.

August 25, 1840.

Second Report of a Committee of the British Association, consisting of Sir J. HERSCHEL, Prof. WHEWELL *and* Mr. BAILY, *for revising the nomenclature of the Stars, appointed at Newcastle*, 1838.

THE revision of the northern hemisphere and the constellations visible in Europe has been continued by Mr. Baily, by carefully tracing the just and most authentic limits of the existing and recognised constellations, and by a careful examination of the several stars, in the course of which many singular instances of confusion and error in naming and placing have been detected. This process, which involves an investigation of the history of each star, and of the designations it has received from each of its observers, and in the several catalogues in which it occurs, is nearly complete, and may be considered as clearing the ground for a systematic nomenclature of the northern stars, as well as for an effective table of synonyms of each star.

In the southern hemisphere, or rather in those constellations which are only visible to an observer in that hemisphere, Sir John Herschel has continued and nearly completed a chart of *those stars only*, and of *all those stars* which are distinctly visible to the naked eye in a clear night, in which chart each star is represented of its true magnitude, according to a scale, in which the total interval from the stars of the first magnitude to the lowest inserted, in place of six degrees, is made to consist

of eighteen, so as to subdivide each magnitude into three. The final assignment of these magnitudes, resting on the collation and inter-comparison of an extensive series of observations made for that express purpose with the naked eye, occasionally assisted by a common opera-glass, has been a work of much time and labour, and is not yet quite completed. Nor till this is accomplished, can any further progress be made in the re-arrangement of the southern constellations, which, at present, are in a state of great confusion.

A small part only of the grant of 50*l.*, devoted by the Association to this object, has been expended; but the whole will, no doubt, be required; and your Committee, therefore, recommend its continuance.

Signed, on the part of the Committee,

J. F. W. Herschel.

Report of a Committee for the reduction of Lacaille's Stars in the Cœlum Australe Stelliferum.

The reductions of all the stars in Lacaille's *Cœlum Australe Stelliferum* are finished, and Mr. Henderson's assistant is at present arranging the results in the form of a catalogue, which, however, could not be completed in time for this meeting. The completed portion, so far as finished, has been transmitted to Mr. Baily, to be used in the construction of the new catalogue of the Astronomical Society. No money has been spent during the year; but, of course, a renewal of the grant will be desirable.

Signed, for the Committee, J. F. W. Herschel.

Report of the Committee, consisting of Sir J. Herschel, Professor Whewell, Professor Peacock, Professor Lloyd, *and* Major Sabine, *appointed to superintend the scientific cooperation of the Association in the Researches relative to Terrestrial Magnetism.*

In consequence of the measures adopted as detailed in the last report of this Committee, a very extensive system of magnetical corresponding observations has been organized, embracing between thirty and forty stations in various and remote parts of the globe, provided with magnetometers, and every requisite instrument, and with observers, carefully selected, and competent to carry out at most, if not in all the stations, a complete series of two hourly observations, day and night, during the whole period of their remaining in activity, together with monthly term-observations, at intervals of two minutes and a

half. Of these observatories, that at Dublin, placed under the immediate superintendence of Professor Lloyd, has been equipped and provided for by the praiseworthy liberality and public spirit of the University of that metropolis. Those at Toronto, the Cape of Good Hope, St. Helena and Van Diemen's Land, as also the two itinerant observatories of the Antarctic expedition, by the British Government; those of Madras, Simla, Singapore and Bombay, by the Honourable East India Company; to which are to be added ten stations in European and Asiatic Russia, and one at Pekin, established by Russia; two by Austria at Prague and Milan; two by the Universities of Philadelphia and Cambridge in the United States; one by the French Government at Algiers; one by the Prussian at Breslau; one by the Bavarian at Munich; one by the Spanish at Cadiz; one by the Belgian at Brussels; one by the Pacha of Egypt at Cairo; one by the Rajah of Travancore at Trevandrum in India; and one by the King of Oude at Lucknow.

In addition to this list, it has recently also been determined by the British Government (at the instance of the Royal Society) to provide for the performance of a series of corresponding observations, both magnetic and meteorological, at the Royal Observatory at Greenwich, under the able superintendence of the Astronomer Royal. In Norway, negotiations, in which M. Hansteen has taken an especial interest, have been for some time carrying on for establishing an observatory of a similar description at Hammerfest. A great number of magnetic and other instruments available for this service, it appears, have been left at Kaafiord by M. Gaymard, acting for the "Commission Scientifique du Nord," under the directions of the French Ministry of the Marine, all which instruments, through the efficient intervention of M. Arago, it is understood, will be placed at the disposal of the observer or observers who may be appointed to conduct the observations. To complete the establishment, however, certain instruments, as well as registry-books, &c. are still requisite. The Council of the Royal Society have undertaken to supply these from the Wollaston Donation Fund.

As regards the magnetic observatory at Breslau, under the direction of M. Boguslawski, your Committee have to report, that in order to secure the establishment of that station, and to place it on an equal footing with the rest, certain instruments, &c. required to be provided, for which no funds existed, or could be made available on the spot, viz. a bifilar and a vertical-force magnetometer, with the requisite reading-tele-

scope, and a set of registry-books. As, owing to the actual circumstances of that observatory, there appeared no prospect of these requisites being otherwise supplied,—as the station appeared to your Committee a desirable one, and as M. Boguslawski was willing and desirous to lend his aid to this great combined operation, by taking on himself the laborious duty of conducting the observations,—your Committee conceived, that although possibly transgressing in some degree the strict wording of their powers, they were only acting up to their spirit in devoting a portion (185*l.*) of the funds placed at their disposal, to supplying them at the expense of the Association. Unwilling to claim any privilege, or establish any precedent for the smallest deviation from the strict literal interpretation of a money grant, your Committee suggest to the meeting the propriety of ratifying, by an express act of recognition, the application of the above-mentioned sum. A letter from M. Boguslawski, dated the 22nd July, 1840, announces the safe arrival of the instruments and books in question, and the consequent complete state of instrumental equipment of the Breslau Observatory, expressing at the same time his sincere thanks for the assistance accorded him.

By returns from the several stations authorized by the British Government, so far as yet received, it appears that the observatories at the Cape and at St. Helena might be expected to be complete, and ready for reception of the instruments in July. From Van Diemen's Land no accounts have yet been received. At Toronto, where the greatest delays and difficulties were to be expected, and have been experienced, the observatory was so far advanced at the date of Mr. Riddell's last communication, as to leave no doubt of its completion in time for the regular observation of the August term. Meanwhile, in this, as at the other stations, all observations practicable under the actual circumstances of each, are made and regularly forwarded. And here your Committee would especially call attention to the extremely remarkable phænomena exhibited at Toronto on the 29th and 30th May, when, by great good fortune, a most superb Aurora appeared at the very time of the term-observations.* The phænomena of this Aurora (which was remarkable for the extent and frequency of the *pulsating waves*, alluded to in that part of the report above cited, p. 47, relating to this subject,) are very minutely and scientifically described by Mr. Riddell. But what renders the occurrence particularly interesting is the fact, that during the whole time of the visible appearance of this Aurora, on the night from

* See table of the terms, Report of the Council of the Royal Society, p. 31.

the 29th to the 30th, as well as for some hours previous, while it might be presumed to be in progress, though effaced by daylight, all the three magnetical instruments were thrown into a state of continual and very extraordinary disturbance. In fact, at $6^h\ 25^m$ in the morning of the 29th, the disturbance in the magnetic declination during a single minute of time carried the needle over 10′ of arc; and during the most brilliant part of the evening's display (from $3^h\ 25^m$ Gött. M. T. to $4^h\ 35^m$,) the disturbances were such as to throw the scales of both the vertical- and horizontal-force magnetometers out of the field of view, and to produce a total change of declination amounting to 1° 59′. It should also be remarked, that the greatest and most sudden disturbances were coincident with great bursts of the auroral streamers. The correspondence, or want of correspondence, of these deviations with the perturbations of the magnetic elements observed in Europe, and elsewhere, on the same day, cannot fail to prove of great interest. Should it fortunately have happened that Captain Ross has been able to observe that term at Kerguelen's Land, which is not very far from the antipodes of Toronto, an indication will be afforded whether or not the electric streams producing the Aurora are to be regarded as diverging from one magnetic pole or region, and converging to another*.

Your Committee cannot conclude this report without congratulating the Association, and the scientific world in general, on the extensive interest inspired, and the vast range of observation consequently embraced by these operations, which, so far as any accounts have hitherto reached them, appear to be so far going on prosperously in all its parts, and to promise results fully answerable to every expectation of its promoters. Neither would they feel justified in their own eyes, were they to omit expressing their deep and grateful sense of the indefatigable personal exertions of Major Sabine throughout the whole of its progress, both in carrying on a most voluminous correspondence, in ordering, arranging and dispatching in-

* In reference to the Aurora which had been seen at Toronto in Upper Canada on the 29th of May, and to the magnetic perturbations by which its appearance had been accompanied, the Astronomer-Royal stated, that the term-day of the 29th and 30th of May had also been kept at the Royal Observatory at Greenwich; that an Aurora was seen there also on the 29th, and that the disturbances of the declination magnetometer exceeded in amount any which had been observed there on previous occasions. Not having brought the observations with him, Mr. Airy could not state whether their comparison with the curves of the Toronto Observatory, which Major Sabine had laid before the Section, would manifest an accordance between the disturbances at the two stations, a point of the highest interest as to the nature and extent of these.

struments, and facilitating, by constant attention and activity, those innumerable details which are involved in a combination so extensive,—a combination which, but for those exertions, your Committee are fully of opinion, must have been greatly wanting in that unity of design and cooperation which now so eminently characterizes it.

Signed, on the part of the Committee,

J. F. W. HERSCHEL.

Referring to the magnetical observatory at Breslau, mentioned in this report, MAJOR SABINE read the following letter from its director, M. von Boguslawski, received since the meeting had commenced.

Breslau, September 7, 1840.

MY DEAR SIR,—I have the pleasure to inform you, that during the last magnetic term, viz. on the 28th and 29th August, I have made observations with the two magnetic instruments provided by the British Association. Notwithstanding the Michaelmas Term of our University has began, I have succeeded in engaging and instructing a double number of observers sufficient to place them at the declination magnetometer in the magnetic cabinet, as well as at the horizontal, and at the vertical-force magnetometers in the great room of the observatory. The observations hitherto made can, however, only be considered as observations of the magnetic variations, because there are several masses of iron fixed in the buildings. The prospect of obtaining a separate magnetic observatory being still distant, I feel myself highly indebted to Professor Lloyd for the assistance his paper "On the Mutual Action of Permanent Magnets, &c." has afforded me. By these instructions I have succeeded in effecting what at first seemed to be impossible, namely, to place the declination magnetometer, the bifilar instrument, and the vertical-force magnetometer, *in the same room of the present magnetic cabinet*, and to put them in equilibrium. How this is to be done by three small fixed subsidiary magnetic bars, I shall hereafter explain to Professor Lloyd; and if he agrees with me, all three instruments will be placed in the magnetic cabinet at the next term.

However, I shall use for a declination magnetometer the second magnetic bar received with the horizontal force magnetometer, instead of the present bar of four pounds, in order to obtain small correction-constants. I shall then expect with patience the establishment of a proper magnetic observatory, so as to begin to make absolute and daily observations. Please to communicate this in my name to the meeting of the British Association at Glasgow; and have the kindness to express to them my regret, that on account of the necessary arrangements I have to make, I am prevented from accepting their honourable invitation, and assisting at their instructive assembly.

(Signed) HENRY VON BOGUSLAWSKI.

Major Edward Sabine.

Major Sabine also presented to the Section, at the request of M. Kupffer, Director-general of the magnetical observatories of Russia, several copies of a report addressed by that gentleman to the Imperial Academy of Sciences at St. Petersburg, entitled, "Sur les Observatoires Magnétiques fondés par ordre des Gouvernemens d'Angleterre et de Russie, sur plusieurs

points de la surface terrestre." In this report, the Russian observatories, acting on the same system of observation, both magnetical and meteorological, as those of England, are enumerated as follows:—"La science doit au gouvernement Russe, et surtout à la protection puissante du ministre des finances, M. le Comte Cancrine, et à l'incessante activité du chef de l'état major du corps des ingénieurs des mines, M. le Général Tcheffkine, l'établissement des stations magnétiques suivantes :

Stations.	*Directeurs.*
St. Pétersbourg	M. Kupffer, Directeur-Général.
Cathérinebourg	M. Roschkoff, } Ingénieurs des Mines.
Barnaoul	M. Prange, 1er } Ingénieurs des Mines.
Nertchinsk	M. Prange, 2eme } Ingénieurs des Mines.
Kazan	M. Simonoff, } Directeurs des Observatoires Astronomiques.
Nikolaïeff	M. Knorre, } Directeurs des Observatoires Astronomiques.
Tiflis	M. Philadelphine, Prof. au Gymnase.
Sitka (Côte N. O. de l'Amérique)	MM. Homann et Fwanoff.
Helsingfors (Finland)	M. Nervander, Prof. Extraor. à l'Université.
Pékin* (China)	M. Gaschkevitsch, Membre de la Mission Ecclesiastique."

The copies of M. Kupffer's report were accompanied by a letter, expressing his regret that the necessary and pressing duty of instructing the directors of the observatories, in regard to the system to be pursued, prevented him from attending the meeting of the British Association at Glasgow, which he had otherwise intended to have done.

Report on the reduction of Meteorological Observations made at the Equinoxes and Solstices, on the part of a Committee appointed by the British Association at Newcastle, consisting of Sir J. Herschel *alone.*

Sir J. Herschel, referring to his report of last year for the reasons why the reduction of these observations was not immediately commenced, reports further, that the same reasons delayed any effective commencement of the work until very lately; but that, owing to several wanting series of observations having at length come to hand, so as to render the series for the years 1835–6–7–8 tolerably consecutive, at least, for several localities, your Committee considered it advisable to wait no longer, but proceed to work with the materials in hand. Accordingly, having cast the plan of operations for the comparison and projection of

* A la station de Pékin nous aurons, si non autant d'observations que des autres stations, au moins les observations les plus importantes.

the barometric oscillations in those years, (to which, for the present, your Committee propose to limit their proceedings, till it shall appear whether a further and more complete comparison, including the thermometric changes, and especially the correspondence of the winds, seems likely to lead to any valuable conclusions,) the reduction, arrangement and projection of the several series of observations was confided to the able and zealous hands of W. R. Birt, Esq., who is now actively employed in the operation, and who has enabled your Committee to lay before the meeting, as specimens of the mode of proceedings, the tabulation and projection of the observations made in the British Isles in the year 1836, which are accordingly submitted for inspection.

In the discussion of these observations it has been found advantageous to divide the stations from which they have emanated into groups, according to geographical proximity, the chief of which are the group of the British Isles, that of the continent of Europe and the North American, South African and Indian groups. Each of these groups is referred by applying the differences of longitude to the times of observation to a central station; and the projected curves, in which the abscissæ are the mean times at that station, and ordinates the reduced barometric altitudes, exhibit at one view the correspondence or disagreement of the barometric movements for all the stations of the group. The numbers which serve for the projections are tabulated in the skeleton forms annexed, which appear well adapted for general adoption in such reductions, and of which, therefore, half a dozen blank copies are annexed as specimens for such members as may take an interest in the subject.

The projection of these curves is the first step in the process of reduction contemplated; and even in the very limited range afforded by the specimens now presented, affords ground for interesting remark. Thus, we see, that the march of the barometer in the only two Irish stations which have furnished observations (Markree and Limerick), while agreeing well with each other, differs most decidedly from its corresponding march in all the English stations, which, on the other hand, offer a good correspondence *inter se*. A letter from Mr. Birt on this subject is annexed to the present report.

It would be premature at present to enter fully into the details of the further steps contemplated in these reductions, as they will be, of necessity, materially influenced by the aspect under which the subject shall present itself in its progress, and especially by the discussion of one or two of the most complete series, among which, thanks to American zeal and industry, the

group including the United States promises to be the most prominent.

Only a very trifling sum (under two pounds) has been hitherto expended (for the printing, by Messrs. Stewart and Murray, of the skeleton forms) out of the original grant of 100*l.*; but the continuance of the grant will be required to meet the further requisite expenses.

It is only justice to Mr. Birt to observe, that his part of the work appears to be executed with great care and judgment.

(Signed) J. F. W. HERSCHEL.

Mr. Birt's Letter, alluded to in the above Report.

Metropolitan L. and S. Institution, September 3, 1840.

DEAR SIR,—I herewith inclose the four sheets of curves mentioned in my last, also the tables of reduced barometric readings from which they are projected. The curves of England and Ireland generally differ, in some cases considerably, with the exception of those observed in December 1836, on which occasion the similiarity between the Markree, Oxford, London, and Ashurst curves especially, as their apices occur about the same hour, is interesting. The occurrence of the apices of the Edinburgh, Halifax, and Oxford curves at later periods, and in the order here mentioned, appears to indicate a progression of the barometric undulation from the north or north-east; and some of the remaining sheets also indicate a progressive movement.

I have not yet proceeded either to rounding off the curves, or to reading off the altitudes on the hour-lines. In the first instance, the undulations only which form the hourly observations assume a rising and falling in straight lines, will probably require a gentle rounding, so that the summit should pass through the point; for I see clearly, as you observed, that the points must not be interfered with, on account of the similar flexures in different curves. Do you consider any advantage would be gained from combining curves that are evidently similar, so that means of those similar curves may be obtained from similar altitudes above or below the mean-line, by bringing the apices and flexures on the same vertical ordinates, allowing for difference of longitude? The general dissimilarity of the curves obtained in Great Britain and Ireland, has suggested this to me also, that in future observations of the kind, it would be desirable to have the stations augmented, and, if possible, the observation of a complete elevation and depression at each.

I hope you will receive the present sheets in good time for the meeting,

And remain, dear Sir,

Yours very respectfully,

W. R. BIRT.

P.S.—In the Halifax curve of September, there are probably two errors. I have accordingly left the curve incomplete.

The scale I have used is 1·5 of the larger divisions, equal ·1 of an inch.

Sir John F. W. Herschel.

On the Temperature and Conducting Power of different Strata. By Professor FORBES.

IN this report, Professor Forbes gave the results of the observations made at Edinburgh during the year 1839, upon

thermometers sunk to depths of 3, 6, 12 and 24 French feet into trap rock, pure loose sand, and sandstone. The details for the years 1837 and 1838 were laid before the British Association at Birmingham. Combining with these the observations for 1839, Professor Forbes exhibited the curves derived from the three years' observations, and gave, in a tabular form, the results for the three years, as follows:

Values of A (one of the constants in the formula used in connecting the results*).

	In trap.	In sand.	In sandstone.
For 1837	1·164	1·176	1·076
1838	1·173	1·217	1·114
1839	1·086	1·182	1·049

Values of B (the other constant).

	In trap.	In sand.	In sandstone.
For 1837	−·0545	−·0440	−·0316
1838	−·0641	−·0517	−·0345
1839	−·0516	−·0498	−·0305

Variation reduced to 0°·01 Centigrade.

	In trap.	In sand.	In sandstone.
For 1837	58·1 feet	72·2 feet	97·3 feet.
1838	49·3	61·8	91
1839	59·2	63·5	100

Velocity of propagation for one foot of depth.

	In trap.	In sand.	In sandstone.
In 1837	7·5 days.	7·1 days.	4·9 days.
1838	6·8	6·8	3·6
1839	7·8	7·2	4·6

Report on the Action of Osler's Anemometer at Edinburgh.

I BEG to report, that Mr. Osler's Anemometer has been erected at Edinburgh, according to the desire expressed by the British Association at Birmingham, and that the members of the Astro-

* The formula in the notation of M. Quetelet is

$$\text{Log. } \Delta_p = \text{A} + \text{B}p$$

Where Δ_p represents the Annual Range in centigrade degrees at a depth p in French feet. A is the logarithm of the Superficial Range, and B is a constant determining the propagation downwards, and proportional to $\sqrt{\frac{\text{specific heat}}{\text{conductivity}}}$ of the soil. The values of A and B are deduced from the Annual Ranges alone.

nomical Institution have afforded every facility for its erection, and have removed their camera-obscura for that purpose.

Mr. Osler has furnished the instrument below prime-cost, but I regret to say, that the unavoidable expenditure for putting the instrument in working order, carriage, and placing it in its present position, amounts to 31*l.*; so that the sum of 60*l.*, granted by the Association, has been exceeded by 11*l.* I have, however, the satisfaction of stating, that the Anemometer is now in complete work, under the superintendence of Prof. Henderson and Mr. Wallace, of the Edinburgh Observatory. J. D. Forbes.

Glasgow, September 23, 1840.

On the part of a *Committee appointed for the purpose of causing a plate to be engraved for printing paper ruled in squares,* Prof. Forbes reported,—

That the plate was engraved, and that the paper, 22 inches by 26, and ruled in squares of one tenth of an inch, each tenth line being stronger than the others, was ready for the service of the members of the Association, at cost price, on application to Messrs. Johnston, Engravers, Edinburgh.

Report on the Application of a Portion of the Sum of Fifty Pounds, voted by the British Association at its Meeting at Birmingham, in 1839, *for Discussion of Tide Observations. By the Rev.* W. Whewell.

(With a Plate.)

A portion of this sum has been expended upon calculations, having for their object to determine the effect of the moon's declination upon the tides. The determination of this correction is attended with peculiar difficulties, and has hitherto been incompletely effected. These difficulties arise from this: that the moon's mean declination is different in different years, through a cycle of eighteen years, the period of revolution of her nodes. The inclination of her orbit to the equator varies from about 18° 20′, its amount in 1829 and 1830, to 28° 40′, its amount in 1837 and 1838. Hence, if we attempt to determine the declination correction (of height, for instance) by taking the difference of the height from the mean height (allowance being made for other corrections), we refer to a variable standard. Accordingly, if we find from the observations the mean semimenstrual inequality for the successive years, it will be different in consequence of the different mean declinations in successive years; and it is only by taking a series of nine or more years that we

can obtain the absolute mean semimenstrual inequality, and consequently the absolute correction for declination applicable to all years alike. This being known to be the case, I was disposed to take advantage of an opportunity which occurred of discussing a series of several years' tide observations, with a view to the verifying in fact these theoretical features of the correction tables, and determining the correction for declination. Mr. Dall, the Harbour Master at Leith, had made a series of tide observations, extending from 1827 to 1839, which I had every reason to believe to be accurate; and Mr. Ross, of the Hydrographer's office, had, for his own satisfaction, begun to arrange these observations, with a view to discussions relative to lunar declination and parallax. The latter gentleman undertook, at my request, to conduct his discussion in such a manner that it might bring into view such results as I have above described. The arrangement and discussion of thirteen years' observations of tides (involving the management of above 18,000 numbers given by observation, and double the number extracted from tables,) was, of course, a business of very great labour and time; but as this task was not originally suggested by the British Association, nor directed exclusively to objects pointed out by it, I thought it my duty to confine my expenditure within a sum very disproportionate to the magnitude of the labour. Mr. Ross has been paid *20l.* for his discussion of the above-mentioned heights, with a view to the declination correction. The result of this discussion is very nearly what I had anticipated. The semimenstrual lines taken for different years, differ by the effect of the different mean declination. Thus the correct mean of the height of high water for each hour of transit, is about six inches less in 1837 than in 1829, and this difference is balanced by a difference in the declination correction which is to be applied to this mean. The declination correction is greater in 1837 than in 1829 for equal declinations. The difference, however, is not constant, but increases with the declination, which agrees with what the theory indicates. The curves which express this correction, deviate considerably from each other at the higher declinations. This result suggests an improved method of applying the declination correction to tide observations, which, however, requires to be further considered and examined before it can be confidently recommended: I mean, a method of using a different semimenstrual inequality and different declination correction for every different period of the moon's nodes. On this subject it may hereafter be possible to speak more decidedly.

W. WHEWELL.

Another portion of the sum placed at my disposal has been expended upon calculations and operations performed by Mr. Bunt. These calculations were in the first place directed to the determination of the form of the curve of rise and fall of the tides at Bristol. This determination was the more desirable, inasmuch as calculations were in progress at the Admiralty (under my directions) for the purpose of determining the form of the curve of the rise and fall at Liverpool and at Plymouth. The results of these calculations have been laid before the Royal Society, and are now printed by them in the Philosophical Transactions, as the twelfth series of my Researches on the Tides. The accompanying communication from Mr. Bunt contains the result of his investigations on this subject. The thing principally discussed was the displacement of the summit of the curve of rise and fall; that is, the difference of the time of high water actually observed, and the time obtained by bisecting the interval between equal altitudes, before and after high water. The main object was, to refer this displacement to its proper argument. It was natural to suppose that it depended mainly upon the height of the tidal wave, and, consequently, upon the age of the moon; and hence would principally consist of a semimenstrual inequality. But by the discussions, it appears that there is, besides this fact, one which depends upon the solar parallax, and also others. This would lead, as Mr. Bunt remarks, to a suspicion that meteorological causes are concerned in producing the result; the subject, however, is as yet not free from difficulty. I have also employed Mr. Bunt in other discussions, with a view to further improvements in our knowledge of the laws of the tides, especially with reference to two points: —the determination of the best anterior epoch, or period, at which that anterior transit of the moon is to be assumed which governs the tide:—and the solar corrections for parallax and declination. The excellence of the Bristol observations made with Mr. Bunt's machine, and of his modes of discussing the observations, induce me to believe that some progress may still be made in this inquiry; but the investigation is not yet completed. I have also taken the liberty of directing Mr. Bunt to perform an operation not precisely included in the terms of the grant made to me for the present year, but closely connected with it, and forming an almost necessary sequel to a large operation performed at the expense of the Association in preceding years; I mean, a repetition of the levelling of a portion of the level line in the neighbourhood of the recent landslip in Devonshire. The southern extremity of the line leveled from the Bristol Channel to the English Channel is at Axmouth. When

the great landslip took place in that neighbourhood, it might naturally be suspected that a part of the level line might be disturbed. A moment's reflection made this appear improbable, since the movement seemed to be confined to the chalk and the clay below it; whereas the terminus of the level line was bedded in the red marl. Still, if the movement of the ground were the result of an earthquake, even the inferior strata might have been slightly stirred; and this appeared to be exactly one of the cases, the decision of which was contemplated in the project of the level line. I therefore requested Mr. Bunt to repeat the levelling of the line from the mark in the church tower, in the village of Axmouth, down to the shore, where is the granite block which forms the terminus of the line, a distance of six sevenths of a mile. In July of the present year this operation was performed (with the same instruments as before), and it appeared that the mark in the church tower was above the mark in the block . . . . 5·8836 feet, which in July 1838 had been found to be . . . 5·8805 feet. The difference, one twenty-seventh of an inch, may be considered as a proof that there has been no sensible change. Mr. Bunt also leveled from the granite block, about 230 yards, to another bench mark eastwards, or towards the landslip, but found no difference of any importance. The expense of this operation, 10*l*., I have taken the liberty of including in the account for tide discussions.

W. Whewell.

"Dear Sir,

"I send you the results I have obtained from an elaborate investigation of ten years' observations of the 'Displacement of Summit' of the tide-gauge curves. The observed quantities themselves being so small, seldom exceeding 5 or 6 minutes, I at first thought that they scarcely admitted of being treated in a similar manner to the ordinary observations of time and height, in which the corrections are gradually obtained, by approximation. On further consideration, however, I determined to try; not knowing in what way to improve upon my former results. I therefore drew on the sheets a new line of observation (cutting off only the diurnal inequality), to a vertical scale of 3 times the size of my old one, which had always been a scale of 40 min. per inch. This afforded me sufficient size to go to work, on my former principles of approximation, by drawing in, on the line of observation, successive pencil curves of semimenstrual inequality, lunar parallax, and declination, and of solar correction, from the corrections first obtained,

and arranging the *residues* (which would have been otherwise too small), so as to improve the first corrections. The accidental irregularities of the observations, being of course also magnified, gave me a very irregular line to work from; notwithstanding which, I believe the attempt at improvement by approximation has been as successful in this instance as it has proved on former occasions.

"You will perceive that the curves of Lunar Declination $\left\{\begin{matrix}26^\circ\\10^\circ\end{matrix}\right\}$ are almost exactly similar to the curves of Lunar Parallax $\left\{\begin{matrix}55'\\60\end{matrix}\right\}$; the effects of the *larger* declinations agreeing with those of the *smaller* parallaxes, and the curves crossing each other at almost exactly the same nodal points, viz. $3\frac{1}{2}^{h}$ and $8\frac{1}{2}^{h}$ of transit.

"There is not the same agreement between the solar curves of declination and parallax; yet it is observable that neither of these pairs of curves produces a loop, as the lunar curves do; the curve of 22 (large) declinations, like that of $8''\cdot45$ (small) parallax, always keeping *above* the other, except at the hour of $8\frac{1}{2}$, where the curves touch, but do not cross.

"The points at the middle of each hour of transit were laid down, without any alteration, from the *differences* of the two parcels of observations, after taking the averages. The straightness of the axis is arbitrary.

"The *magnitude* of the corrections is quite as great as could be expected from observations which do not themselves average more than about five minutes.

"The great difference of effects corresponding to the maximum and minimum of solar parallax, would lead to a suspicion that meteorological causes were concerned in producing them; the maximum and minimum of solar parallax nearly coinciding with midwinter and midsummer. Such causes cannot, however, explain the forms assumed by the curves corresponding with the arrangements of the observations for the maxima and minima of *lunar* parallax and declination; especially the former, which is more clearly independent of weather or season. There is also a diurnal inequality plainly to be seen in many parts of the curve of observation, which cannot arise from merely local or meteorological causes.

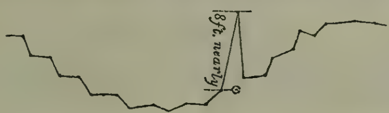
"I shall be very glad to know what you think of these curves, and how they bear on the theory. I am quite satisfied that they very nearly represent any agreement that exists between the observations and the arguments to which they have been referred. I shall also be glad to be informed of any results which you may

have arrived at in the course of your own investigations of the same subject.

"I have also made some progress in the discussion of the heights with a view to the determination of the best anterior epoch, and to the solar correction. I have laid down the two years' observations made by means of my machine, but have not obtained any of the correction curves as yet.

"The two tide-gauges for the East Indies are very nearly completed. I have had a visit from another engineer officer in the Company's service, a Lieut. Ludlow, who stayed here three or four days to study my machine. Lieut. Elliott has written to say he intends coming again to Bristol, as soon as the new instruments are finished, in order to make himself more perfectly acquainted with all their details. Both these gentlemen expressed themselves as being highly pleased with my tide-gauge. It has been working now for more than seven months without the slightest derangement, or the loss of a single observation.

"I do not think that I mentioned to you the extraordinary tide which occurred here in October, 1838, when the water in our river rose to nearly 8 feet above its proper height, in consequence of a hurricane, as shown by the adjacent heights of the series of tides, from which it differs by that quantity, thus:



"I am, dear Sir, yours very respectfully,

"Thos. G. Bunt."

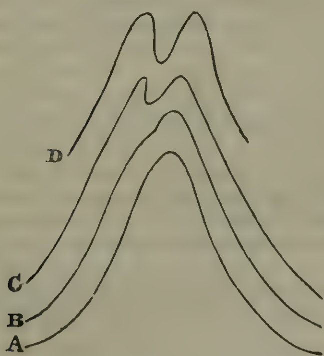
"Bristol, 27th Jan., 1840."

On Waves.—By a Committee, consisting of Sir J. Robison and J. S. Russell, Esq.

All the objects which had been confided to this Committee having been fully accomplished, the report now presented was to be considered as final. The objects originally committed to them for investigation were—the Phænomena of Waves propagated in Liquids; the connexion of these Phænomena with the resistance of Liquids to the motion of Floating Bodies; and the nature of the connexion which subsists between the Tidal Wave and Mr. Russell's great solitary Wave of Translation. Since the publication of their former report, the phænomena of Waves had occupied the attention of eminent mathematicians, who had endeavoured to deduce from first principles the curi-

ous phænomena which the Committee had observed, so as to reconcile theory with experiment. The Astronomer Royal, Mr. Green, and Professor Kelland, had all been engaged on the subject; and the two latter had published memoirs in the Transactions of Cambridge and Edinburgh, in which they had succeeded in obtaining from analysis many of the very singular results published in the former report of the Committee. There still, however, remained difficulties which they had not been able to conquer; but as Mr. Kelland was about to lay before the Section his own investigations, it had become unnecessary to include them in this report.

The subject which had chiefly engaged the Committee during the last year, was the conclusion and discussion of observations on the Tidal Wave of the Frith of Forth. This tidal wave presented some very singular features; and, for the purpose of determining its phænomena with accuracy, a standard line had been levelled with great accuracy, under the direction of Mr. James Aden, C.E., and observations made at a great number of stations, the rise and fall of the tide being observed every five minutes. In this channel were observed the singular phænomena of four tides, or two double tides, every day; and, on some occasions, six tides, or two triple tides were observed. These had all been accurately laid down from the levels; and it appeared that the top of high water rose at Stirling to the height of sometimes as much as ten feet above the level of the tides at Leith. The tides were of this form:



A, a common Tide-Wave.

B, the Tide-Wave of Leith.

C, the Tide-Wave of Alloa.

D, Tide-Wave near Stirling.

Mr. Russell had formerly intimated his expectation that this second tide was the great southern tide-wave of the English

Channel entering the Forth before the northern tide-wave, coming round by the Shetland Islands, and afterwards exaggerated,—first, by the dislocation of the wave, and next, by the narrowing of the channel; and the velocities of these respective waves appeared to be just what was necessary to this effect. He had also found a similar appearance in the tide-wave of the river Tay, which he attributed to the same cause. These phænomena appeared to throw considerable light on the mechanical constitution of tidal waves. It appeared that, like the great wave of Translation, tidal waves could not only meet and cover each other without losing their individuality, but that they could also pass over each other when going in the same direction.

That part of the duties of the Committee which related to the connexion of the phænomena of waves with the resistance of fluids to solids, had been devolved upon them under a separate name, as the Committee on Forms of Vessels, and would be reported by them under a separate head. The wave-form of vessels, however, had been now proved to possess so many advantages, that its use seemed likely to become general, and thus a great change would be effected in the naval architecture.

Geology and Geography.

Professor Johnston presented to this Section a portion of his *Report on Inorganic Chemistry, relating to the nature and origin of Coal.*

On the subject of the *application to the Trustees of the British Museum, for enlarged exhibitions in illustration of Recent and Fossil Conchology**, the Marquis of Northampton reported,—

That the Trustees of the British Museum had resolved, that a commencement of such an arrangement should be made, and that the duplicates of their fossil shells and other Invertebrata, should be handed over to Mr. Gray, for the purpose of being arranged with their recent analogous species and genera, where there are any such.

On British Fossil Reptiles. By Professor Owen, F.R.S.

Prof. Owen reported,—That in order to complete his materials for the continuation of his Report on British Fossil Rep-

* Report for 1839, p. xxiii.

tiles, he had inspected many considerable collections in different parts of England, and collected abundance of new information, which he fully expected to be able to digest into regular order, so as to present a continuation of his report on the subject at the next meeting.

Mr. Stevenson's *Report on the relative Level of Land and Sea* was read.

Natural History.

At the last Meeting of the British Association, a Committee was appointed for *procuring drawings illustrative of the Species and their details of the Radiate Animals of the British Islands, to accompany a Report of the state of our knowledge of such Animals,* and the sum of 50*l.* was placed at their disposal.

Respecting the state of our knowledge of two divisions of the Radiate Animals, the Committee feel it unnecessary to furnish any report, these departments being undertaken by individual members of the Committee, whose researches are either published, or are now in course of publication*. With regard to the remaining portion, the Acalepha, they are persuaded it cannot be effectually investigated and illustrated, except when the artist and the naturalist are combined in the person of one individual. The Committee, therefore, after an expenditure of only two pounds, now bring forward the drawings they have had prepared, and, for the reasons assigned, beg leave to discontinue the further prosecution of the subject.

The Committee appointed at the last Meeting of the British Association, for *the investigation of the Marine Zoology of Great Britain, by means of the dredge,* have to report the expenditure of 15*l.* out of the 50*l.* granted for that purpose. The state of the weather, which prevented dredging in the open sea during a great part of the summer, and the difficulty of obtaining observations sufficiently precise in information respecting species, have been the causes which have operated against them, and caused the expenditure of so small a portion of the grant. A series of queries, and printed formulæ to be filled up with the results of the dredging excursions, were prepared and

* Johnston's Zoophytes, and Forbes's Echinodermata.

distributed. A Sub-Committee, consisting of Mr. Thompson, Mr. Ball and Mr. Forbes, examined a considerable portion of the west coast of Ireland; Mr. Patterson undertook the examination of the north-east coast of the same country; and Mr. Forbes dredged the coasts of the Isle of Man. The results of these researches were very satisfactory, and the products in every case carefully noted down in the printed formulæ. The Committee recommend further researches, and propose that the dredging-papers be laid by for the present, until a sufficient amount of data be obtained to warrant the publication of a summary of their contents.

On the recommendation (a grant adopted in 1839) for *engraving Skeleton Maps for recording the distribution of Plants and Animals*, the Committee reported at length the measures they have taken for executing these maps, on certain principles, believed to be of undoubted importance. They have caused three maps to be prepared and lithographed, one of the British Isles, and one of each hemisphere. The work was entrusted to Mr. Nichol, the lithographer, under the superintendence of Mr. Brand. This member of the Committee having been for some time engaged in preparing tables or catalogues for the Botanical Society of Edinburgh, which should include a variety of topographical details, it was thought proper to carry on both these plans together. On the maps, the details chiefly sought to be given with fulness are the river and mountain systems, the measures of the chief elevations, and important lakes. The maps are not yet considered by the Committee, though repeatedly revised, to be complete; but they recommend that, after having been finally settled, copies should be printed off, and sold at the lowest remunerating price to all who may wish copies for natural history purposes. As an illustration of the way in which these maps may be usefully employed, the Botanical Society of Edinburgh caused to be represented in coloured outlines on their maps, from another stone, the 'sections' of the earth's surface, which are an important part of the system of arranging botanical information before alluded to. The numbers being attached to the several sections on the map so coloured, immediate reference can be made to the catalogue sheets which have been prepared for botanical registration by the Botanical Society. (Copies of the maps and catalogue sheets were presented to the meeting.)

Statistics.

Prof. Johnston reported the progress made by the Committee appointed at the Newcastle Meeting *to inquire into the Statistics of the Mining Districts.*

Mechanical Science.

On the Forms of Vessels.—By a Committee, consisting of Sir J. Robison, J. S. Russell, Esq., and James Smith, Esq.

On the Translation of Foreign Scientific Memoirs.

At the Meeting of the British Association at Newcastle in 1838, a Committee was appointed for the purpose of procuring and publishing translations of foreign scientific memoirs, and a sum of 100*l.* was placed at their disposal: and at the Meeting at Birmingham in 1839, a further sum of 100*l.* was allotted for the same object. The memoirs translated in the first year, under the superintendence of the Committee, and at the expense of the Association, were—

1. Remarks on the arrangement of magnetical observatories, and a description of the instruments to be placed in them (with one plate), by Weber.
2. Method to be pursued during the magnetical term-observations by Gauss.
3. Extract from the daily observations of magnetical declination during three years, at Göttingen, by Gauss.
4. Description of a small portable apparatus for measuring the absolute intensity of terrestrial magnetism (with one plate), by Weber.
5. On the graphical representations of the magnetic term-observations (with two plates), by Gauss.
6. On a new instrument for the direct observation of the changes of the intensity in the horizontal portion of the terrestrial magnetic force, by Gauss.
7. On the arrangement and use of the bifilar magnetometer, by Weber.

For the translation and publication of these in Taylor's Scientific Memoirs, the first year's grant of 100*l.* was paid to Mr. Taylor.

In the present year, Ohm's memoir, entitled "The Galvanic Circuit investigated mathematically," has been translated at the expense of the Association, and given to Mr. Taylor, for the seventh and eighth numbers of the "Scientific Memoirs." The Association have also paid for seven plates contained in the seventh number, representing the lines of magnetic declination, inclination and intensity computed by M. Gauss's theory. The sums paid for these plates and for the translation of Ohm's

memoir, and the plate which accompanies it, amount to 63*l*., which is the whole charge for the present year. The Committee report that translations have been gratuitously presented to them by Major Sabine, of the five undermentioned memoirs on magnetical instruments, and on subjects of prominent interest in mathematical and physical science.

1. *Gauss.*—General theory of terrestrial magnetism.
2. *Encke.*—On the method of least squares.
3. *Bessel.*—On the determination of the axes of the elliptic spheriod of revolution, which most nearly corresponds to the existing measurements of arcs of the meridian.
4. *Weber.*—Description and use of a transportable magnetometer.
5. *Bessel.*—On the barometrical measurement of heights.

The Committee placed these translations in the hands of Mr. Taylor, by whom they have been printed in the sixth, seventh and eighth numbers of the "Scientific Memoirs." The Committee further acknowledge the receipt of a translation of Rudberg's experiments "On the expansion of Dry Air," gratuitously presented by Professor Miller, of Cambridge. This translation has also been placed in Mr. Taylor's hands, and will make a part of the eighth number of the "Scientific Memoirs."

Varieties of Human Race.

Queries respecting the Human Race, to be addressed to Travellers and others. Drawn up by a Committee of the British Association for the Advancement of Science, appointed in 1839.

At the meeting of the British Association held at Birmingham, Dr. Prichard read a paper "On the Extinction of some varieties of the Human Race." He pointed out instances in which this extinction had already taken place to a great extent, and showed that many races now existing are likely, at no distant period, to be annihilated. He pointed out the irretrievable loss which science must sustain, if so large a portion of the human race, counting by tribes instead of individuals, is suffered to perish, before many interesting questions of a psychological, physiological and philological character, as well as many historical facts in relation to them, have been investigated. Whence he argued that science, as well as humanity, is interested in the efforts which are made to rescue them, and to preserve from oblivion many important details connected with them.

At the suggestion of the Natural Historical Section, to which Dr. Prichard's paper was read, the Association voted the sum of

£5 to be expended in printing a set of queries to be addressed to those who may travel or reside in parts of the globe inhabited by the threatened races. A Committee was likewise appointed by the same Section to prepare a list of such questions. The following pages, to which the attention of travellers and others is earnestly invited, have, in consequence, been produced. It is right to observe, that whilst these questions have been in preparation, the Ethnographical Society of Paris has printed a set of questions on the same subject for the use of travellers. It has been gratifying to perceive the general similarity between the questions proposed by the French savans who compose that Society, and those which had been already prepared by the Committee; but the Committee is bound to acknowledge the assistance which, in the completion of its task, it has derived from the comprehensive character and general arrangement of the Ethnographical Society's list. The following queries might have been considerably extended, and much might have been added to explain the reasons and motives on which some of them are founded. Such additions would, however, have inconveniently extended these pages, and, in part, have defeated their object. The Committee has only further to express its desire that the Association may continue its support to the interesting subject of Ethnography, and that their fellow-members will aid in bringing these queries under the notice of those who may have it in their power to obtain replies. Britain, in her extensive colonial possessions and commerce, and in the number and intelligence of her naval officers, possesses unrivalled facilities for the elucidation of the whole subject; and it would be a stain on her character, as well as a loss to humanity, were she to allow herself to be left behind by other nations in this inquiry.

It will be desirable, before giving direct answers to the questions proposed in the following list, that the traveller should offer, in his own terms, a description of the particular group of human beings, which he may have in view in drawing up his list of answers, seeing that the replies, however accurate and replete with useful information, may fail in some particulars to give a complete idea of the people to whom they relate.

Physical Characters.

1. State the general stature of the people, and confirm this by some actual measurements. Measurement may be applied to absolute height, and also to proportions, to be referred to in subsequent queries. The weight of individuals, when ascertainable, and extreme cases, as well as the average, will be in-

teresting. What may be the relative differences in stature and dimensions, between males and females?

2. Is there any prevailing disproportion between different parts of the body? as, for example, in the size of the head, the deficient or excessive development of upper or lower extremities.

3. What is the prevailing complexion? This should be accurately defined, if possible, by illustrative and intelligent example, such as by comparison with those whose colour is well known. The colour of the hair should be stated, and its character, whether fine or coarse, straight, curled, or woolly. The colour and character of the eyes should likewise be described. Is there, independently of want of cleanliness, any perceptible peculiarity of odour?

4. The head is so important as distinctive of race, that particular attention must be paid to it. Is it round or elongated in either direction, and what is the shape of the face, broad, oval, lozenge-shaped, or of any other marked form? It will contribute to facilitate the understanding of other descriptions, to have sketches of several typical specimens. A profile, and also a front view should be given. In the profile, particularly notice the height and angle of the forehead, the situation of the meatus auditorius, and the form of the posterior part of the head. It will also be desirable to depict the external ear, so as to convey the form and proportion of its several parts. The form of the head may be minutely and accurately described by employing the divisions and terms introduced by craniologists, and the corresponding development of moral and intellectual character should in conjunction be faithfully stated. So much of the neck should be given with the profile as to show the setting on of the head. The advance or recession of the chin, and the character of the lips and nose, may likewise be given in profile. The front view should exhibit the width of forehead, temples, and cheek-bones, the direction of the eyes, and the width between them: the dimensions of the mouth. When skulls can be collected or examined, it would be desirable to give a view in another direction, which may even be done, though with less accuracy, from the living subject. It should be taken by looking down upon the head from above, so as to give an idea of the contour of the forehead, and the width of the skull across from one parietal protuberance to the other.

5. State whether the bones of the skull are thick, thin, heavy, or light. Is it common to find the frontal bone divided by a middle suture or not? Note the form of the outer orbitar process, which sometimes forms part of a broad scalene triangle, with

the vertex downwards. How are the frontal sinuses developed? Observe whether the ossa triquetra are frequent, or otherwise; whether there be frequent separation of the upper part of the os occipitis; the relative situation of the foramen magnum. In regard to the bones of the face, notice the position of the ossa nasi and unguis; the former sometimes meet nearly or quite on the same plane, whilst, in others, they meet at an angle. The former character is strongly marked in many African skulls. State the form of the jaw-bone, shape of the chin, and observe the angle of the jaw, the position and character of the teeth, and their mode of wear; and if they have any practice of modifying their form or appearance, let this be stated. The malar bones have already been noticed, but they may require a more minute description.

6. When the opportunity can be found, observe the number of lumbar vertebræ, since an additional one is said to be common in some tribes.

7. Give the length of the sternum as compared with the whole trunk; and also some idea of the relative proportion between the chest and the abdomen.

8. What is the character of the pelvis in both sexes, and what is the form of the foot?

9. The form of the scapula will also deserve attention, more especially as regards its breadth and strength; and the strength or weakness of the clavicle should be noticed in connection with it.

10. The internal organs, and blood-vessels will with greater difficulty be subjected to examination; but it may be well here to remark, that varieties in these may prevail locally in connection with race.

N.B.—Peculiarities may exist, which cannot be anticipated in queries, but which the observer will do well to notice amongst his answers to anatomical questions.

11. Where a district obviously possesses two or more varieties of the human race, note the typical characters of each in their most distinct form, and indicate to what known groups or families they may belong: give some idea of the proportion of each, and state the result of their intermixture on physical and moral character. When it can be ascertained, state how long intermixture has existed, and of which the physical char acterstend to predominate. It is to be observed, that this question does not so much refer to the numerical strength or political ascendency of any of the types, but to the greater or less physical resemblance which the offspring may bear to the parents, and what are the characters which they may appear to derive from

each: whether there is a marked difference arising from the father or the mother belonging to one of the types in preference to another; also whether the mixed form resulting from such intermarriage is known to possess a permanent character, or after a certain number of generations to incline to one or other of its component types.

12. Any observation connected with these intermarriages, relating to health, longevity, physical and intellectual character, will be particularly interesting, as bringing light on a field hitherto but little systematically investigated. Even when the people appear to be nearly or quite free from intermixture, their habits, in respect of intermarriage within larger or smaller circles, and the corresponding physical characters of the people, will be very interesting.

Language.

13. Do the natives speak a language already known to philologists, and if so, state what it is; and notice whether it exhibit any dialectic peculiarities, as well as the modifications of pronunciation and accentuation which it may offer. State also the extent to which this dialect may be used, if limits can be ascertained.

14. If the language be little if at all known, endeavour to obtain a vocabulary as extensive as circumstances will allow, and at least consisting of the numerals, the most common and important substantives *, the pronouns in all persons and numbers, adjectives expressive of the commonest qualities, and, if possible, a few verbs varied in time and person. The vocabulary should be tested by the interrogation of different natives, and more than one person should be engaged in taking it down from their mouths, to avoid, as far as may be, errors arising from peculiarities of utterance or defect of hearing. It is likewise of importance that the system of orthography be duly indicated and strictly adhered to.

15. Endeavour to take down some piece of native composition, such as the ordinary phrases employed in conversation, and any other piece of prose which may be attainable; and specimens of metrical composition if such exist. Though these would be of comparatively little use without translation, yet independently of this some importance is to be attached to the metrical compositions if they have a national character and are widely diffused; and, in this case, it might be possible to express some of their airs in musical characters. A specimen of known composition translated into their language, may also be given, such as the

* The names of mountains, lakes, rivers, islands, &c.

first chapter of Genesis, the fifteenth chapter of Luke's Gospel, and the Lord's Prayer.

16. Endeavour to ascertain whether the language is extensively spoken or understood, and whether there are different languages spoken by men having similar physical characters obviously connecting them as a race, or if differing somewhat in this respect, inhabiting a particular geographical tract. When such groups are said to possess different languages, endeavour, as far as possible, to ascertain their number, the sources whence each is derived, and the languages to which it is allied; and also the circumstances, geographical or political, which may account for these distinctions.

[For further information connected with the investigation of languages, reference is made to a short essay on this subject read to the Philological Society of London.]

Individual and Family Life.

17. Are there any ceremonies connected with the birth of a child? Is there any difference whether the child be male or female?

18. Does infanticide occur to any considerable extent, and if it does, to what causes is it to be referred, want of affection, deficient subsistence, or superstition?

19. Are children exposed, and from what causes, whether superstition, want of subsistence or other difficulties, or from deformity, general infirmity, or other causes of aversion?

20. What is the practice as to dressing and cradling children, and are there any circumstances connected with it calculated to modify their form; for example, to compress the forehead, as amongst the western Americans; to flatten the occiput, as amongst most Americans, by the flat straight board to which the child is attached; to occasion the lateral distortion of the head, by allowing it to remain too long in one position on the hand of the nurse, as amongst the inhabitants of the South Seas?

21. Are there any methods adopted, by which other parts of the body may be affected, such as the turning in of the toes, as amongst the North Americans; the modification of the whole foot, as amongst the Chinese?

22. How are the children educated, what are they taught, and are any methods adopted to modify their character, such as to implant courage, impatience of control, endurance of pain and privation, or, on the contrary, submission, and to what authorities, cowardice, artifice?

23. Is there anything remarkable amongst the sports and amusements of children, or in their infantile songs or tales?

24. At what age does puberty take place?

25. What is the ordinary size of families, and are there any large ones?

26. Are births of more than one child common? What is the proportion of the sexes at birth and among adults?

27. Are the children easily reared?

28. Is there any remarkable deficiency or perfection in any of the senses? It is stated, that in some races sight is remarkably keen, both for near and distant objects.

29. To what age do the females continue to bear children? and for what period are they in the habit of suckling them?

30. What is the menstrual period, and what the time of utero-gestation?

31. Are there any ceremonies connected with any particular period of life?

32. Is chastity cultivated, or is it remarkably defective, and are there any classes amongst the people of either sex by whom it is remarkably cultivated, or the reverse, either generally or on particular occasions?

33. Are there any superstitions connected with this subject?

34. What are the ceremonies and practices connected with marriage?

35. Is polygamy permitted and practised, and to what extent?

36. Is divorce tolerated, or frequent?

37. How are widows treated?

38. What is the prevailing food of the people? Is it chiefly animal or vegetable, and whence is it derived in the two kingdoms? Do they trust to what the bounty of nature provides, or have they means of modifying or controlling production, either in the cultivation of vegetables, or the rearing of animals? Describe their modes of cooking, and state the kinds of condiment which may be employed. Do they reject any kinds of aliment from scruple, or an idea of uncleanness? Have they in use any kind of fermented or other form of exhilarating liquor, and, if so, how is it obtained? What number of meals do they make? and what is their capacity for temporary or sustained exertion?

39. Describe the kind of dress worn by the people, and the materials employed in its formation. What are the differences in the usages of the sexes in this respect? Are there special dresses used for great occasions? and, if so, describe these, and their modes of ornament. Does any practice of tattooing, piercing, or otherwise modifying the person for the sake of ornament, prevail amongst the people? N.B. Such modifica-

tions not to be blended with other modifications used as signs of mourning, &c.

40. Have the people any prevailing characteristic or remarkable modes of amusement, such as dances and games exhibiting agility, strength or skill?

41. Are games of chance known to the people, and is there a strong passion for them?

42. Do the people appear to be long- or short-lived? If any cases of extreme old age can be ascertained, please to state them. Such cases may sometimes be successfully ascertained by reference to known events, as the previous visits of Europeans to the country. Is there a marked difference between the sexes in respect of longevity?

43. What is the general treatment of the sick? Are they cared for, or neglected? Are any diseases dreaded as contagious, and how are such treated? Is there any medical treatment adopted? Are there any superstitious or magical practices connected with the treatment of the sick? What are the most prevailing forms of disease, whence derived, and to what extent? Is there any endemic affection, such as goitre, pelagra, plica, or the like? With what circumstances, situations, and habits do they appear to be connected, and to what are they referred by the people themselves?

44. Where there are inferior animals associated with man, do they exhibit any corresponding liability to, or exemption from disease?

45. Do entozoa prevail, and of what kind?

46. What is the method adopted for the disposal of the dead? Is it generally adhered to, or subject to variation?

47. Are any implements, articles of clothing, or food, deposited with the dead?

48. Is there any subsequent visitation of the dead, whether they are disposed of separately, or in conjunction with other bodies?

49. What is the received idea respecting a future state? Does this bear the character of transmigration, invisible existence about their accustomed haunts, or removal to a distant abode?

Buildings and Monuments.

50. What are the kinds of habitations in use among the people? Are they permanent or fixed? Do they consist of a single apartment, or of several? Are the dwellings collected into villages or towns, or are they scattered, and nearly or quite single? If the former, describe any arrangement of them in streets or otherwise which may be employed.

51. Have any monuments been raised by the present inhabitants or their predecessors, and more especially such as relate to religion or war? State their character, materials, and construction. If they are still in use amongst the people, state this object, even if they should be of the simplest construction, and be little more than mounds or tumuli. If these monuments are no longer in use, collect, as far as possible, the ideas and traditions of the natives regarding them, and, if possible, have them examined by excavation or otherwise, taking care to deface and disturb them as little as possible.

52. In these researches be on the look out for the remains of the skeletons of man or other animals, and, if discovered, let them be preserved for comparison with those still in existence.

Works of Art.

53. Let works of art, in metal, bone, or other materials, be likewise sought and preserved, and their similarity to, or difference from implements at present in use amongst the people of the district, or elsewhere, be noted.

54. When a people display their ingenuity by the extent or variety of their works of art, it will not only be desirable to describe what these are, but also the materials of which they are constructed, the modes in which these materials are obtained, the preparation which they undergo when any is required, and the instruments by which they are wrought. Such particulars will not only throw light on the character and origin of the people, but will, directly or indirectly, influence the commercial relations which may be profitably entered into when commerce alone is looked to. When colonization is contemplated, the facts contained in the replies to these queries will point out the mutual advantages which might be obtained by preserving, instead of annihilating, the aboriginal population.

Domestic Animals.

Are there any domestic animals in the possession of the people? Of what species are they? Whence do they appear to have been derived, and to what variety do they belong? Have they degenerated or become otherwise modified? To what uses are they applied?

Government and Laws.

55. What is the form of government? Does it assume a monarchical or democratic character, or does it rest with the priests?

56. Are the chiefs, whether of limited or absolute power, elective or hereditary?

57. Is there any division of clans or castes?

58. What are the privileges enjoyed by or withheld from these?

59. What care is taken to keep them distinct, and with what effect on the physical and moral character of each?

60. What laws exist among the people? How are they preserved? Are they generally known, or confided to the memory of a chosen set of persons? What are their opinions and regulations in reference to property, and especially the occupation and possession of the soil? Does the practice of hiring labourers exist among them?

61. Have they any knowledge or tradition of a legislator, to whom the formation of laws is ascribed?

62. Do they rescind, add to, or modify their laws? and how?

63. Are they careful in the observance of them?

64. What are their modes of enforcing obedience, and of proving and punishing delinquency?

65. How are judges constituted? Do their trials take place at stated periods, and in public?

66. How do they keep prisoners in custody, and treat them?

67. What are the crimes taken cognizance of by the laws? Is there gradation or commutation of punishment?

Geography and Statistics.

68. Briefly state the geographical limits and character of the region inhabited by the people to whom the replies relate.

69. State approximatively the number of inhabitants. As this is an important, but very difficult question, it may not be amiss to point out the modes in which the numbers may be ascertained. The people themselves may state their number with more or less accuracy, but it should be known whether they refer to all ranks and ages, or merely comprehend adult males, who may be mustered for war, or other general purpose requiring their combination. In this case state the apparent proportion between adult males and other members of families. The number of habitations in a particular settlement may be counted, and some idea of the average numbers of a family be given. Where the people inhabit the water-side, the number and dimensions of their craft may be taken, and some idea of the proportion between the number of these and of the individuals belonging to them, may be formed. In drawing conclusions from observations of this kind, it will be necessary to have due regard to the different degrees of density or rarity in which, from various causes, population may be placed.

70. Has the number of inhabitants sensibly varied, and within what period?

71. If it have diminished, state the causes; such as sickness, starvation, war, and emigration. When these causes require explanation, please to give it. If the inhabitants are on the increase, is this the result of the easy and favourable circumstances of the people causing an excess of births over deaths; or is it to be assigned to any cause tending to bring accessions from other quarters? State whether such causes are of long standing, or recent.

72. Is the population generally living in a manner to which they have been long accustomed, or have new relations with other people, and consequently new customs and practices, been introduced?

73. If the people, being uncivilized, have come under the influence of the civilized, state to what people the latter belong, how they are regarded, and what is the kind of influence they are producing*. State the points of their good influence, if any, and those of an opposite character, as the introduction of diseases, vices, wars, want of independence, &c.

74. Is there any tendency to the union of races? how is it exhibited, and to what extent?

Social Relations.

75. What kind of relationship, by written treaty or otherwise, subsists between the nation and other nations, civilized or not? Have they any intercourse by sea with other countries? Do any of them understand any European language? Or are there interpreters, by whom they can communicate with them?

76. Are they peaceable, or addicted to war? Have they any forms of declaring war, or making peace? What is their mode of warfare, either by sea or land? their weapons and strategy? What do they do with the slain, and with prisoners? Have they any mode of commemorating victories by monuments, hieroglyphics, or preservation of individual trophies, and of what kind? Have they any national poems, sagas, or traditions respecting their origin and history? Where Europeans have introduced fire-arms, ascertain the modes of warfare which have given place to them.

State whatever particulars respecting their origin and history are derived, either from traditions among themselves or from other sources.

* This question will comprise the existence of missions—the success or the want of it from causes connected with missionaries themselves or others.

Religion, Superstitions, &c.

77. Are the people addicted to religious observances, or generally regardless of them?

78. Do they adopt the idea of one great and presiding Spirit, or are they polytheists?

79. If polytheism exist, what are the names, attributes, and fables connected with their deities, and what are the modes in which devotion is paid to each? Are any parts of the body held sacred, or the reverse? Do they offer sacrifices, and are they of an expiatory character, or mere gifts?

80. Have they any sacred days or periods? fixed or moveable feasts, or religious ceremonies of any kind, or any form of thanksgiving or other observance connected with seasons?

81. Have they any order of priests; and if so, are they hereditary, elective, or determined by any particular circumstance?

82. Is the religion of the people similar to that of any other people, neighbouring or remote? If different, are they widely so, or dependent on particular modifications, and of what kind?

83. In what light do they regard the religion and deities of neighbouring tribes?

84. Is there any idea of an inferior order of spirits and imaginary beings,—such as ghosts, fairies, brownies, and goblins; and how are they described?

85. Have they any notions of magic, witchcraft, or second sight?

86. What ideas are entertained respecting the heavenly bodies? Have they any distinction of stars, or constellations? and if so, what names do they give them, and what do these names signify?

87. Are they in any manner observed with reference to the division of the year, and how?

88. If time is not divided by observations of those bodies, what other mode is adopted? and do observances connected with them rest with the priests or chiefs?

89. When the traveller, by personal acquaintance with the language, or by means of competent assistance from interpreters, can freely converse with the people, it will be desirable that he should form some idea of their amount of intelligence, their tone of mind with regard to social relations, as respects freedom, independence, or subserviency, and their recognition of moral obligations, and any other psychological character which observation may detect; and more especially such as may contribute to an estimation of the probable results of efforts to develope and improve the character.

NOTICES

AND

ABSTRACTS OF COMMUNICATIONS

TO THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

AT THE

GLASGOW MEETING, AUGUST 1840.

ADVERTISEMENT.

The Editors of the following Notices consider themselves responsible only for the fidelity with which the views of the Authors are abstracted.

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MATHEMATICS AND PHYSICS.

On the mean Apsidal Angle of the Moon's Orbit. By Dr. FORBES.

By limiting the terms in the expression of the integral equation to the first four, viz. those depending on

$\cos \overline{c\,\theta - a}$, $\cos \overline{2\,\theta - 2\,m\,\theta + 2\,\beta}$, $\cos \overline{2\,\theta - 2m\,\theta + 2\,\beta - \theta\,c + a}$

or the evection, and $\cos \overline{2\,\theta - 2\,m\,\theta + 2\,\beta + c\,\theta - a}$, he derived the number expressing the ratio of the apsidal angle to the whole circle, and found it to be ·00843; the result given in the *Mécanique Céleste*, by Laplace, being the same. A decided influence was ascribed to the inclination of the moon's orbit to the ecliptic, and the corrections that require to be made for it; also, to the value due to h, or the space described by the radius vector in the unit of time, in the disturbed orbit, compared with the same in the simple elliptic theory. The circumstance that this quantity may be so easily determined presents a beautiful evidence of the law of gravitation, and of the truth of the Newtonian theory, and may be of material importance in the theory of the moon.

An Account of the Observatory erecting near Glasgow. By Professor NICHOL.

He stated that when he was appointed to the office he holds in the University, the state of the Macfarlan Observatory gave him much anxiety, as in consequence of its age it was in nowise fitted to be of service

to astronomical science, nor did its site encourage any attempt to repair it; but the strong desire existing both in the College and among the citizens of Glasgow for the erection of a suitable establishment, speedily relieved his embarrassment, and by the union of the two parties and the patronage of Government, means were soon provided to accomplish all good ends. The Professor then adverted at some length to the principles on which the plan of the Institution was arranged. It was his strong conviction, that although the repetition of the same observations at different observatories was to a certain extent necessary for the elimination of errors, this had been much overdone, and time and labour thereby lost. He was strengthened by the opinion of all the eminent men with whom he corresponded, in his resolution not to enter in Glasgow on the line pursued with such brilliant success at Greenwich, Edinburgh, Armagh, &c., but to devote the new observatory to investigations which lay for the most part out of the way of these other establishments, and which in the present state of astronomy are numerous and important. It was a first point with him therefore to see to the provision of an efficient equatorial, and, if easily attainable, a large reflector. Circumstances had hitherto prevented the completion of the arrangements in reference to the equatorial, but these would soon be overcome, and he could venture to promise an instrument of this kind of first-rate power. He had obtained almost by accident two reflectors, by Ramage, one of 25 focal feet length, to which he meant to affix Sir John Herschel's collimator, and another of 55 feet in length and 23 inches diameter. This one was fit only for occasional observations, and he did not in the mean time intend to attempt to give it more than a mere meridional sweep. But although the instruments now referred to may be the ones chiefly used in the researches to which the observatory will in the first instance be devoted, a good meridian instrument was clearly necessary, inasmuch as several of the inquiries about to engage them depended upon the nicest determinations of this description. Accordingly, urged by the feeling that in so far as they could go, every department of the institution should be equipped in the best style, they ordered from Munich a transit circle, the telescope of which is 8 feet focal length, and $6\frac{1}{4}$ inches diameter. The Professor described this instrument at length from diagrams. He called particular attention to the fact that it read by microscopes, and that as the circle carrying the microscopes was not in the same place as the circle with the graduated limb, the objection having reference to the hazard from traction, forcibly urged by Professor Airy, was entirely obviated. The Professor then stated that a magnetical observatory, with the three instruments, at which Gauss's terms would be noted, was meant to be attached to the other establishment, and that he hoped to be able to pay attention to some of the more important problems in meteorology. He could not promise success, but this he could well promise, that his life should be thoroughly and singly devoted—now that the means were in his power—to the realization of objects of importance to astronomy.

On a New Apparent Polarity of Light. By the Astronomer Royal.

Sir David Brewster had, at the Liverpool and Newcastle Meetings, stated a most extraordinary fact respecting the solar spectrum or coloured image formed by the agency of a prism, when viewed through thin plates of glass or mica. Most members of the Section were aware, but to some it might be new, that the light in the solar spectrum could be so managed as to be entirely free from all mutual intermixture or jumble of different colours. When this was done, suppose this pure spectrum to be so turned as that its violet end lay to the right hand and the red end towards the left, and suppose the pupil of the eye to be half covered by a thin piece of glass or mica—if the piece of glass or mica be made to cover that half of the pupil which is towards the violet end of the spectrum, numerous parallel bands are seen to cross the spectrum. This fact was long since observed by Mr. Talbot; but the extraordinary fact observed by Sir D. Brewster was, that upon turning the plate of mica so as to cover the half of the pupil next the red end of the spectrum, all the bands completely disappeared. This fact appeared so inexplicable to Sir David Brewster, that he pronounced it to indicate a new and hitherto unobserved polarity of light. From this opinion he ventured to dissent, and he should endeavour to explain to the Section how complete a solution of the facts was afforded by the undulatory theory of light. But before he proceeded, he must premise that his own experience of the facts differed from that of Sir D. Brewster, though so slightly, that the circumstances he deemed material might readily be overlooked. He should only say that he had consulted a friend respecting these discrepancies long before he was aware of their important bearing on the explanation. The peculiarly short-sighted character of his eye, was perhaps the occasion of their becoming so perceptible to him. The facts, as he observed them, were :— 1. When a spectrum is viewed *out of focus,* bands are formed by placing a piece of mica, of a proper thickness, so as to cover the half of the pupil next the violet end. 2. No bands are formed with any thickness of mica if it be placed on the side of the red end. 3. When the eye is too distant to see the spectrum distinctly, upon moving the mica from the violet end, bands are seen advancing in the same direction over the spectrum. 4. When the eye is too near to see the spectrum distinctly, the bands appear to move in the opposite direction. 5. If the eye be so far off, and the spectrum is consequently seen so indistinctly, that the ruddy portions are nearly mingled with the blue, upon covering with the mica half the pupil next the violet end, bands are seen well-defined, but narrow. 6. If the eye and mica approach the position of distinct vision of the spectrum, the bands become broader, and near the position of distinct vision sometimes disappear; on approaching still nearer, the bands re-appear and become narrower, but he thinks are not seen so distinctly as when the eye is too far off (this may, however, depend on the practical difficulty of that part of the experiment). 7. Bands which are visible when the mica is on the violet side, and invisible when it is on the red side, never occur when

the spectrum is pure. 8. Bands are frequently visible when the spectrum is pure; but in that case they can be seen equally well, whether the mica be placed on the violet or on the red half of the pupil. Mr. Airy then gave a rapid sketch of the leading features of the undulatory theory,—showed how a series of rays or a wave in passing through a convex lens, being more retarded in passing through the middle of the lens than through the edges, was bent so as to be convex to the lens after passing through it, and thus was made to converge to a focus. Next, if a thin plate of a transparent substance, like mica, were made to cover half the lens, one half the waves were retarded; and thus, when the lens represented the eye, and the place of the focus the retina, interference was produced, which, when the distance of the retardation bore a certain relation to the distance of two waves (or the wave length), might obliterate the light altogether. Next, if a luminous point be looked at, it never is seen as a point, but as a small circle of light; and if a retarding plate be interposed, under some circumstances bands or fringes parallel to the edge of the retarding plate are generated in the circular image of the luminous point; and those bands are not symmetrically arranged from the centre of the circular image; and the amount of their deviation from symmetrical position depends on the retardation of the ray in passing through the plate of mica, &c. and therefore depends upon the colour of the ray, or upon its position in a spectrum. Thus, if we examine the bands formed by different kinds of light, similar to those from successive points in a spectrum, the bands formed by these different kinds of light will be shifted successively more and more to the right (or to the left as the case may be). Now, if different luminous points be superimposed (as suppose points of the different coloured lights contained in white or solar light), in general it would be easily understood that the bands belonging to one colour would fall unsymmetrically between the bands in the circular image of another colour; and thus if a multitude of them were superimposed, they would tend to obliterate each other. But if the luminous origins of the different streams of coloured light did not coincide, but were arranged side by side in the same order as the order of their successive retardations by the mica, (which supposition is exactly represented by supposing the origins to be the successive points of a spectrum, formed either by refraction or by diffraction,) then it might happen that the shift of the centre of each image, in proceeding from one to the next, was exactly equal to the shift of the bands in relation to the centre of the image; and if this shift took place in the proper direction, the bands formed by the light from the different sources would unite and would strengthen each other; but if the shift took place in the opposite direction, the bands would be more widely separated than before, and would obliterate each other. It resulted from a mass of calculation to which he had subjected these conditions, that the relation of the wave lengths of the different colours, in passing from the violet to the red end, was such, that, under favourable circumstances, a retarding plate being made to cover the half of the eye next the violet end, the bands came together, and so strengthened each

other and became obvious to sense; but on turning the plate to the red end, the bands separated and obliterated each other. Thus the phænomenon became a simple consequence of the undulatory theory.

On Professor Powell's *Measures of the Indices of Refraction for the lines* G *and* H *in the Spectrum. By Sir* David Brewster.

After noticing the discussion between Professor Powell and himself on this subject, the author drew attention to another demonstration of the accuracy of his former statements. In the diagram No. I. he had drawn the group of lines round G, which is a *single* line well marked in the spectrum, and distinctly delineated in Fraunhofer's map. The real line G is not situated in the middle of the group, but much nearer its least refrangible side, and hence the index of refraction, as taken by Prof. Powell from the middle of the group, must have a greater index of refraction than the real line G, whose wave length in the interference spectrum had been determined by Fraunhofer. In reference to the line H the error is much more serious, as appeared from the diagram No. II., in which Sir D. Brewster had represented the two remarkable bands in the violet rays, the least refrangible of which is distinctly marked in Fraunhofer's map with the letter H. Between the central lines of these two bands there are no fewer than fourteen lines in the same map. All the observations made by Fraunhofer, both on the camera spectrum and the interference spectrum, apply to the central line H of the least refrangible of the two bands; but the observations of Prof. Powell, to which the author referred at the Newcastle Meeting, were all taken from an imaginary line bisecting the interval between these two bands, and therefore were of no value as physical data for testing the new theory of dispersion. Prof. Powell has recently given new measures for the real lines G and H, thus admitting the accuracy of Sir D. Brewster's former observations.

On the Decomposition of Glass. By Sir David Brewster.

The author has had occasion to examine the phænomena of decomposed glass, both of that which is found in Italy, of which he has received the finest specimens from Dr. Buckland and the Marquis of Northampton, and of other specimens recently found in making excavations among the ruins of the chapter-house of the cathedral of St. Andrew's. In decomposed glass the decomposition commences in points, and extends itself either in planes so as to form thin films, or in concentric coats so as to form concentric films. When the centres of decomposition are near each other, the concentric films or strata which they form interfere with each other, or rather unite, and the effect of this is that the glass is decomposed in films of considerable irregularity, their surfaces having a finely mammillated appearance, convex on one side and concave on the other. The films

thus formed are of extreme beauty, and afford by transmitted light colours of infinite beauty and variety, surpassing anything produced in works of art. They have the effect of directing, as it were, the compound surface of the solar spectrum, or of sifting and separating the superimposed colours, in a manner analogous to what is produced by colours and absorbing media. Sir D. Brewster has succeeded indeed in producing one or more bands of white light incapable of decomposition by the prism, and there can be no doubt that they will be found to exercise a similar or an analogous action on the heating rings of the thermometric spectrum. In the decomposed glass from St. Andrew's a change of a very different kind is effected. In some cases the siliceous and the metallic elements of the glass are separated in a very singular manner, the particles of silex having released themselves from the state of constraint produced by fusion and subsequent cooling, and arranged themselves circularly round the centre of decomposition; while the metallic particles, which are opake, had done the same thing in circles alternating with the circles of the siliceous particles. This restoration of the silex to its crystalline state is proved by its giving the colour of polarized light, and possessing an axis of double refraction.

The preceding notice was illustrated by diagrams and specimens of the different kinds of glass referred to.

On the Rings of Polarized Light produced in specimens of Decomposed Glass. By Sir David Brewster.

In the course of a series of experiments on the connexion between the absorption of light and the colours of thin plates, published in the Phil. Trans., 1837, the author accidentally observed under the polarizing microscope certain phænomena of polarized tints, of great beauty and singularity. These tints were sometimes linear and sometimes circular, and in some specimens they formed beautiful circular rings, traversed by a black cross, resembling the phænomena of mineral crystals, or those produced by rapidly cooled circular plates or cylinders of glass. Having found in the decomposed glass from St. Andrew's that the siliceous particles had resumed their position as regular crystals, and arranged themselves circularly round the centre of decomposition, he was led to suppose that this was the cause of the phænomena, and that the rings were the effect of the double refraction of the minute crystals. A few experiments, however, overturned this hypothesis, and he was soon satisfied, by a little further investigation, that the phænomena arose wholly from the polarization of the transmitted light by *refraction*, the splendid colours being entirely those of thin plates, which were sometimes arranged so as to have the appearance of concentric rings. The structure by which these effects were produced was compared by the author to a heap of very deep watch-glasses laid one above another. When the thin films were arranged longitudinally, and were inclined to the general surface of the plate, so as to transmit the rays obliquely, the light was still polarized, but only in one plane, namely, a

plane perpendicular to the plane of incidence. When a drop of *water* or *oil* was introduced between the films, the phænomena of *polarization*, as well as of colour, instantly disappeared.

The preceding paper was illustrated by coloured drawings.

On the Cause of the Increase of Colour by the Inversion of the Head. By Sir DAVID BREWSTER.

"It has been long known to artists and tourists that the colours of external objects, and particularly of natural scenery, are greatly augmented by viewing them with the head bent down and looking backwards between the feet, that is, by the *inversion* of the head. The colour of the western sky and the blue and purple tints of distant mountain scenery are thus beautifully developed. The position of the head, however, which I have described, is a very inconvenient one, but the effect may be produced nearly to the same extent by inverting the head so far as to look at landscapes backwards beneath the thighs or under the left arm. It is not easy to describe in any precise language the degree of increase which the colours of natural scenery thus receive, but an idea may be formed of it from the fact, that the colours of distant mountains which appear to me as if of a French-gray colour when viewed with the head erect, appear of a brilliant blue or purple tint with the head inverted. Upon inverting the landscape by reflexion I found that no increase of colour took place. I then viewed the inverted landscape with the head inverted and found the colour to be increased as before. Hence it appears that the increase of colour is not owing to the simple inversion of the object and to our viewing it under unusual circumstances. That the augmentation of tint is not owing to the impression falling upon a part of the retina not so much accustomed to receive such impressions, is obvious from the fact that the tint is the same upon whatever part of the retina the image falls, and it is easy to see that the very same part of the retina is affected whether we look at an object with the head upwards or downwards, or in any other position, provided we look at it directly. In order to acquire some information on this subject, I requested a friend who was unacquainted with any theoretical views that had been advanced, to make some observations on the change of colour of distant mountains. The result of these was to convince him that the increase of tint arose from the protection of the eye from lateral light, owing to the position of the head when inverted. On submitting this opinion to examination, I found that the *tint* was not increased by protecting the eye from lateral rays, even to a much greater extent than is done by the inversion or inclination of the head, and therefore that this could not be the cause of the increase of colour. In this perplexity about the cause of the phænomenon in question, I had an opportunity of observing the great increase of light which took place in an eye in a state of inflammation. This increase was such that objects seen by the *sound* eye appeared as if illuminated by twilight, while those seen by the inflamed eye seemed as if they were illuminated by the direct rays

of the sun. All coloured objects had the intensity of their colours proportionably augmented, and I was thus led to believe that the increase of colour produced by the *partial* or *total* inversion of the head arose from the increased quantity of blood thrown into the vessels of the eye-ball,—the increased pressure thus produced upon the retina, caused from the increased sensibility thus given to the vertical membrane. Subsequent observations have confirmed this opinion; and though I cannot pretend to have demonstrated it, I have no hesitation in expressing it as my conviction that the apparent increase of tint to which I have referred is not an optical but a physiological phænomenon. If this is the case, we are furnished with a principle which may enable us not only to appreciate faint tints which cannot otherwise be recognized; but to perceive small objects, which, with our best telescopes, might be otherwise invisible."

On the Phænomena and Cause of Muscæ Volitantes. By Sir DAVID BREWSTER.

The following are the principal results described in detail in this communication.—1. That in persons of all ages, and with the most perfect eye, transparent filaments or tubes exist in the vitreous humour, and at different distances from the retina. 2. That these filaments float in the vitreous humour, moving about with the motion of the head. 3. That these filaments are seen by means of their shadows on the retina, and are most distinctly visible in divergent light, their shadows being bounded by fringes produced by diffraction or inflexion. 4. That the real *muscæ*, resembling *flies*, are *knots* tied, as it were, on these filaments, and arising from sudden jerks or motions of the head, which cause the long floating filaments to overtop and run into knots. 5. By making experiments with the head in all positions, and determining the limits of the motions of the *muscæ*, by measuring their apparent magnitude, and producing double images of them by means of two centres of divergent light, the author was able to determine their exact place in the vitreous humour, and to ascertain the important fact, that the vitreous humour in the living human eye is contained in cells of limited magnitude, which prevent any bodies which they contain from passing into any of the adjacent cells. Sir David Brewster concluded with the following observations.

"I have dwelt thus *long* on the subject of *Muscæ volitantes*, not only because it is an entirely new one, but also on account of its *practical utility*. Mr. Mackenzie informs us that few symptoms prove so alarming to persons of a nervous habit or constitution as *Muscæ volitantes*, and that they immediately suppose that they are about to lose their sight by *cataract* or *amaurosis*. The details which I have submitted to you prove that the *Muscæ volitantes* have no connexion with either of these diseases, and are altogether *harmless*. This valuable result has been deduced from a recondite property of divergent light, which has only been developed in our own day, and which might

seem to have no bearing whatever of an utilitarian character. And this is but one of numerous proofs which the progress of knowledge is daily accumulating, that the most abstract, and apparently transcendent truths in physical science will sooner or later add their tribute to supply human wants and alleviate human sufferings. Nor has science performed one of the least important of her functions, when she enables us, either in our own case or in that of others, to dispel those anxieties and fears which are the necessary offspring of ignorance and error."

On the Line of Visible Direction along the Axis of Vision. By Sir David Brewster.

In Monsieur D'Alembert's Memoir "On Different Questions in Optics," published in his "Opuscules Mathématiques," tom. i., he has maintained the singular opinion, that distant objects, like the fixed stars, when viewed directly with both eyes, are not seen in their true direction; that is, neither in the direction of the rays which they send to the eye, nor of the line (coincident with it) drawn from the point of incidence in the retina through the centre of visible direction. The author pointed out the fallacy in D'Alembert's reasoning, and thus established, in opposition to the opinion of that distinguished philosopher, the law of visible direction, which he had explained at the Newcastle Meeting.

A Brief Account of the Camera Obscura, and other Apparatus, used in making Daguerreotype Drawings. By Sir David Brewster.

The author exhibited a very perfect apparatus, executed for him by Mr. Thomas Davidson of Edinburgh, who has made some essential improvements on the process. Sir David also exhibited several drawings taken by Mr. Davidson with that apparatus, of various buildings and scenes in Edinburgh. He likewise explained to the meeting the method of executing Photogenic Drawings on paper, as invented by Mr. Fox Talbot, and exhibited to the Section a series of very beautiful drawings executed by Mr. Talbot himself, and presented to him by that distinguished philosopher.

On a Method of Illuminating Microscopic Objects. By Sir David Brewster.

Considering a perfect microscope as consisting of two parts, viz. an illuminating apparatus, and a magnifying apparatus, the author stated, that it was of more consequence that the illuminating apparatus should be perfect, than that the magnifying apparatus should be so; and that the essential part of his method consisted in this; that the rays which form the illuminating image or disc shall have their foci exactly on the

part of the microscopic object to be observed, so that the illuminating rays may radiate, as it were, from the object, as if it were self-luminous. Now this can only be well obtained by illuminating with a single lens, or a system of lenses, without spherical or chromatic aberration, whose focal length, either real or equivalent, is less than the focal length of the object-glass of the microscope. The smaller the focal length of the illuminating lens or system of lenses, the more completely do we secure the condition that the illuminating rays shall not come to a focus either before they reach the object, or after they have passed it. When Dr. Wollaston recommended for an illuminating lens, one of three-fourths of an inch in focal length, in which the microscopic object was placed in a vortex of foci, where the rays crossed in a thousand points both before and after they fell upon the object, he could have had no idea of the new method of illumination. In the construction of a perfect microscope, Sir David Brewster recommended that the illuminating and magnifying apparatus should have separate and similar movements along the same rod or bar, and that the stage for the objects should be unconnected with either, and should have also a motion independent of both.

On an Improvement in the Polarizing Microscope.
By Sir DAVID BREWSTER.

This improvement consists in placing the analysing prism or simple rhomb immediately behind the object-glass, that is, on the side of the object-glass next the eye. The great inconvenience of placing it between the eye-glass and the eye, had induced several skilful observers to reject the prism altogether as an analyser, or to substitute for it a plate of tourmaline, which is quite unfit for any observations in which colour is to be considered. The analysing prism may remain constantly on the microscope behind the object-glass, without in the least injuring the performance of the microscope, and it should have a motion of rotation independent of the body of the microscope.

Extract of a Letter from Col. REID *to Sir* D. BREWSTER.

Bermuda, August 17th, 1839.

DEAR SIR,—I think the accompanying letter, which describes the singular appearance of the sun at Bermuda, which made white objects appear blue, cannot fail to interest you; and if you are able to explain the cause of this, I should be very glad if you would favour me with such explanation. The fact is one familiar to every one here; but I requested Dr. Harvey to put it in writing, expressing what he saw himself, that I might send the account to you. The present collector of the customs at Bermuda was at sea on the 11th of August, the day the same hurricane was passing over St. Vincent; and to him and to the other persons on board, objects appeared, they thought, of a light green or bluish green colour, and the sun had this same appearance. Their vessel was then fifteen miles east of Bermuda. The hurricane reached Barbadoes a little before midnight on the 10th of August, 1831.

Three days ago I had a fine opportunity of observing a waterspout under my house, and could, with a spy-glass, distinctly observe that, *at the surface of the sea*, it was revolving like the hands of a watch, and the same observation was made at a telegraph station near Government House. This is the fifth account, well authenticated, in north latitude : all five revolved in the same way.

Bermuda, 3rd August, 1839.

Dear Sir,—Not having made any notes at the time, I can only proceed to narrate the circumstances, which occurred here in August, 1831, from memory. On the 10th of that month the weather was remarkably fair, but as evening drew near a change took place. The sky began to lower and put on an awful and gloomy appearance. The clouds collected voluminously and very heavily in every direction over the island, indicating a prodigious fall of rain. At this time I do not recollect any threatening of a storm of wind, save a moderately hollow sound of the sea dashing against the shore, but by no means equalling that which we frequently witness at this season of the year when a storm is impending, or has passed by us. Thunder and lightning began to be severe, and the weather more threatening. Next morning, the 11th, I rose early, for the purpose of writing, and soon discovered, the light was so dim, I could not proceed. I removed to another room, and finding my situation not improved, I said in the presence of one of my family, I apprehend a sudden failure of sight. I was then asked if I had not observed a very peculiar appearance of the sun's rays the day before. I had not; but had perceived the floor of the room to look blue, especially where the sun shone on it : indeed every object in the room appeared of a sickly blue colour. The next day, the 12th, a mail-boat was put under weigh for the first time, with a party on board. The day was so mild and tranquil we could only reach a few miles ; the sails, which were new, and pure white, nevertheless appeared to be stained of a bluish colour, and the sea was of a dingy yellow. On the first arrival from the West Indies we heard of the devastation at Barbadoes; but with us there were no subsequent unusual appearances; on the contrary, we had very fair weather, although I heard this singular blue colour was observed even to the coast of America.

(Signed) Augustus Wm. Harvey, M.D.

Sir David Brewster, who communicated Col. Reid's letter, observed, that in the course of a series of experiments on the colour of mixed plates, both as produced by the soft solids compressed between plates of glass, and as exhibited in laminæ of sulphate of lime, and other minerals containing strata of minute cavities filled with fluids, he was led to the opinion that the blue colour of the sun was produced in a similar way by vapour or water in a vesicular state, interposed between the sun and the observer. Owing to this cause, the sun may exhibit any colour, and, in point of fact, he had once seen the sun of a bright salmon colour, in which both red and yellow were mixed with the blue. A similar effect is often produced when the sun is seen in a cold winter morning through the windows of a carriage covered with hoar frost, or when it is seen through vapour similarly deposited. Sir David referred to observations of his own published in the Phil. Trans. for 1837, in which he had shown that the colours of mixed plates were phænomena of diffraction produced by the edges of transparent bodies separating media of different density.

On a remarkable Rainbow observed by Mr. Bowman. *Communicated by Sir* David Brewster.

"On Tuesday morning last, soon after sunrise, as the 'Commodore' steamer, from Liverpool, was making her way up the estuary of the Clyde, a very perfect and brilliant rainbow was observed by the passengers on deck, accompanied by a larger outer bow, with fainter reversed colours, as is not very unusual under the ordinary conditions of rain and sunshine. Nearly in contact with the inner edge of the brighter, or primary bow, were four distinct though smaller ones, parallel to and equidistant from each other, not perfectly continuous, but formed of interrupted segments of circles, the colours of each diminishing in intensity, the faintest being the innermost. In all these minor bows the red and orange were the only colours that were distinctly seen. The water being smooth, the reflexion from its surface was so strong that the normal and secondary bows seemed to be continued below the horizontal line, bending inwards till they almost met and formed nearly two complete concentric circles, the reflected images being scarcely less brilliant than the bows themselves. The rain drops were few, though larger than ordinary, and the reflected image of the sun appeared as a broad band of light on the smooth surface of the water, scarcely less dazzling to the eye than his direct rays. (Above the sun was a canopy of dark cloud, whose lower margin nearly touched his upper limb, and was parallel to the horizon.) I first observed a faint perpendicular light on the north side of the primary bow, and apparently in contact with its outer margin, and as though diverging from it in a tangent. By degrees this shot up higher, and acquired the prismatic colours, which were clearly in the same order as in the primary bow, though fainter. Shortly afterwards a similar tangent was seen on the opposite side, in all respects corresponding, both extending upwards to about the height of the large outer bow. My friend Dr. Black, of Manchester, who was present, first suggested that the lengthened image of the sun upon the smooth water might probably produce these upright lateral columns, the image in this case acting the part of the luminary himself. We had soon an opportunity of testing the soundness of this solution, for in a little time the upper limb of the sun came in contact with the lower edge of the cloud, and as he very gradually disappeared behind it the primary bow became fainter and fainter, till at length it faded entirely away. But the upright lateral columns remained, nay, for a short time appeared brighter and higher, and only disappeared when the more complete obscuration of the sun destroyed the reflexion of his light upon the water."

On remarkable Rainbows. By the Rev. J. Fisher, *M.A., of Rosebank, Dumfries.*

The observations were made on Monday, 1st of June, 1840, while travelling by the coach from Glencairn Manse to Dumfries, nearly at sunset (8 p. m.), the sun being bright and the sky only very partially

clouded. "At first (observes the author), as we were passing over an elevated part of the road, Killness, near New Bridge, a beautiful rainbow was formed, remarkable for the width of its span, the elevation of its arch, as the sun was then low, and also for its vivid colours; still, as the sky became more overcast, the brilliancy of this primary bow increased, and forthwith an upper bow also assumed distinctness, and though the colours were indeed inverted, as having undergone a double refraction and reflection, was almost as bright as the under bow, and besides seemed more remote from it than I had observed before in the formation of the two bows. No sooner were these two distinctly formed, than a supplementary bow began to form to each. But the phænomenon did not end here; for hardly had these supplementary bows been formed, when there appeared within the arch of the under bow, another, and another, and another, and so on to a fifth, in rapid succession; there being now no less than five supplementary bows clearly and distinctly formed; and in one part, particularly where the shower above alluded to had been, though the rain had then seemed almost to cease, I could trace the incipient stage of another supplementary bow, but this only for a short space. The others, however, were distinctly formed throughout the whole arch, and the four first especially, nearly as vivid as the under bow itself.

"Such was the appearance with regard to the under bow; but upon reviewing the upper one, not only was there the first supplementary bow, but also two others, clearly and distinctly formed throughout the whole arch, and only diminished, as to size, distance, and vividness of colours, as in the case of the first lower bows; only the spaces between each supplementary bow belonging to the upper one, seemed larger than between the supplementary bows belonging to the under one. And as in the case of the under bow, its supplementary bows gradually diminished as to the size of the arch and brightness of their colours, in a distinct mathematical proportion; so also with regard to the upper bow, its supplementary bows, *vice versâ*, though they exhibited the exact arrangement of prismatic colours, as did the primary bow to which they belonged, increased their arch over the heavens, diminishing at the same time in width or distance from each other, as well as in the brilliancy of their colours, in the same exact proportion. This whole phænomenon, with ten distinct rainbows, and at one time part of the eleventh, stretching across the heavens, was indeed truly magnificent, and besides, took in a much larger space than I had ever noticed before. The vale of Nith may extend about nine or ten miles across, and in the case of these bows, the one foot seemed near the Barhill, Inwald, and the other near the White hill, Terregles. They first became visible as we were crossing Killness, Ness, Holywood, and continued for nearly a mile without much sensible alteration, only the arches ascending higher and higher (till we arrived at Newton Lodge) as the sun descended. As we approached Dumfries some of the bows gradually disappeared, probably from our having moved out of the proper angle of reflexion. Soon after this the sun sunk below our sensible horizon, and finally showed only the upper part of the larger arches."

On a new case of Interference. *By* A. Bell.

On the Iriscope. *By* Joseph Read, *M.D.*

After noticing the fact of the appearance of colours on plain glass which has been washed and then breathed on, while breathing on the same glass when perfectly dry yield only a gray vapour, the author describes the following experiment.

"Having procured a convex plate of black glass, such as that of a perspective mirror, I smeared its surface with the top of my finger, dipt in a strong solution of Castile soap and distilled water; when dry I polished with a coarse towel until no clouds appeared; I now breathed on it through a glass tube about a foot long and one-third of an inch diameter, when a beautiful series of concentric and variously coloured rings were formed."

The author then notices the analogy of the coloured rings thus obtained with those of Nobili, procured by voltaic agency, and offers remarks on the theory of the subject. An instrument constructed for the purpose of experiment was exhibited.

On an Experiment of Interference. *By* Prof. Powell.

The author refers to an experiment of Mr. Potter (in the Lond. and Edinb. Journ. of Science, May 1840,) in which, under certain peculiar conditions, the central stripe appears *black*, instead of *white*, as required by theory, and in the ordinary form of the experiment. The author repeated the experiment in the *peculiar way proposed*, but still found the stripe in question *white*. His object was to bring it under the notice of the Section, and induce others to examine the question, especially by micrometrical measurements.

On a point in the Wave-Theory as applied to Heat. *By* Prof. Powell.

According to M. Cauchy's theory, the relation between the refractive index and the wave-length is expressed by the formula

$$\frac{1}{\mu^2} = P - Q\left\{\frac{\pi\,\Delta x}{\lambda}\right\}^2 + R\left\{\frac{\pi\,\Delta x}{\lambda}\right\}^4 - \&c.$$

and when λ is very great, compared with Δx, this expression is reduced to its limiting value,

$$\frac{1}{\mu^2} = P \quad \text{or,} \quad \mu = \frac{1}{\sqrt{P}}.$$

This forms the limit of refraction for rays of *all* wave-lengths, *whether of light or of heat*. And as the value approaches this limit, considerable changes in λ will correspond only to small changes in μ.

This deduction is obvious, and has been before made. The limit is easily determined from Mr. Kelland's calculation for all the media examined by Fraunhofer; thus *e. g.* for flint-glass, No. 13, we have

For the ray B . . . . . $\mu_B = 1{\cdot}6277$

For the limit . . . . . $\mu_0 = 1{\cdot}6090$

The present object is to remark the bearing of this point on the theory *of heat*. If this theory be true, all refraction of heat ought to fall within this limit, and probably a considerable portion of the heating rays would have an index not far removed from it. It will be particularly interesting to calculate it for rock-salt, and other diathermanous media, and compare it with the index of the heating rays. The data for rock-salt are given in Professor Powell's report on Refractive Indices, British Association Reports, 1839.

This consideration also explains a difficulty which occurred to Prof. Forbes, who in his Third Series of Researches (§ 2. No. 45—46), having arrived at the conclusion that a wave of heat has a length nearly three times that of red light, regards this as a startling inference, and difficult to reconcile with the small difference existing between the index of refraction for heat and for light. This is just what should result in the above theory.

On the Conduction of Heat. By Professor KELLAND.

The author's object in bringing forward this subject at the present time, he explained to be, to point out the state of our experimental knowledge of the transmission of heat, and to exhibit its total inadequacy to serve as the test of any precise and accurate theory. The following is a brief sketch of the history of the subject. Little had been done before the time of Lambert, who, in 1755, solved one of the most simple problems. Afterwards appeared the writings of Euler. But it was left for Fourier, at the commencement of the present century, to exhibit a theory having about it the characters of truth, adequacy, and extension. For a long time Fourier's memoir was known only to a few, and, as it was based on the Newtonian hypothesis, that *radiation* is proportional to the difference of the temperatures of the radiating body and of the surrounding air, it happened that the interval which elapsed between its production and its publication, to a great extent destroyed its utility. In 1813 Dulong and Petit, by an admirable series of experiments, established another law, taking the indications of the air thermometer as the measure of temperature. This law is, that the cooling of a body depends, not as Newton supposed, on the difference of temperature of the body, and the space into which it cools, but on the difference of exponential functions of the temperatures. The difficulty of the appearance of this law deterred philosophers from attempting its application to any but *one* of the problems. This one was that of the ring. M. Libri read, in 1825, to the Institute, and afterwards published at Florence and in *Crelle's Journal* in Germany, his analysis of this problem. No one appears to have doubted the accuracy of this solution, until, in 1837, the author expressed his conviction that the whole was founded on an erroneous hypothesis relative to the resulting equation. The following year M. Liouville read a paper on the subject to the Institute, which he subsequently published in his own journal. In this paper he points out

clearly the erroneousness of M. Libri's solution, but does not propose any other in its place. M. Liouville states in a note, that Professor Kelland had preceded him in this matter, and promises to supply a solution. Thus, then, one case of theory appears to be made out. Last year the author again brought forward the subject of Dulong and Petit's law, but as experiments were wanting to give solidity to his views, he reserved the publication of his Memoir to a future time. The design of that paper (of which an abstract appeared in the account of the proceedings of the Royal Society of Edinburgh) is this: to show that all the formulæ of Fourier are quite accurate and applicable to physical phænomena. It will be observed that Fourier conceives the external and internal flow of heat to vary as the difference between two quantities, which he calls the temperatures. This hypothesis is not consistent then with nature; but it is not, therefore, altogether valueless; although the difference of temperature does not determine the flow of heat, it does not follow that the difference of no other quantities does so. It is highly probable that the flow of heat is due to the difference between some two things. Now Dulong found that for external radiation, the flow of heat depends on the difference of two exponential functions of the temperature. May it not, then, be the fact, that these exponentials, and not the temperature as measured by the air thermometer, are the elements by which nature proceeds? Why should it be supposed that temperature has any explicit connexion with the matter? Why, in fine, should we desire to retain our preconceived notions relative to internal transmission, when we find another law holds for external radiation? The author ventured on the hypothesis, then, that internal conduction follows the same law as external radiation, viz. that the flow of heat is proportional, not to the difference of temperature, but to the difference of two exponentials of the temperature. To obviate the confusion that would be introduced into our language by such an hypothesis, he further ventured to suggest that the term "thermature" should be adopted as the expression for this exponential function on which the flow of heat depends. This thermature would be the real measure of caloric—temperature of its effect on the thermometer. This quantity "thermature" is nothing else than Fourier's v. All that remains, then, in order to reduce the results of theory to those of experiment, is to substitute for v, on which theory is made to depend, its value in terms of θ, the temperature as marked by experiment. It readily appears that $v = A\left(1 - a^{-\theta}\right)$. The author has tested this result by all the experiments which he could find. But he regretted that a want of experiments rendered it impossible to decide the matter, thus leaving the theory of heat in a most precarious state, whilst its practical applications are become so vastly important. He hoped by his comments to excite some attention to the subject, especially among those who are labouring in the kindred field of the theory of light*.

* Professor Kelland has undertaken, at the request of the General Committee, to draw up a report on this subject, to be presented to the Association.

On the Temperature of the Earth in the deep Mines in the neighbourhood of Manchester. By EATON HODGKINSON.

Mr. Hodgkinson having some years ago received from Professor Phillips four thermometers belonging to the Association, was enabled, through the kindness of the proprietors of the following pits, and other parties connected with them, to institute experiments upon the temperature of the earth in each of them. The salt rock pit, 112 yards deep, belonging to the Marston Salt Company, near Northwich, Cheshire. The Haydock colliery, 201 yards deep, near to Warrington. The Broad Oak coal mine, 329 yards deep, near to Oldham. In the latter pit a thermometer placed in a hole three feet deep, bored in "metal," and closed at the aperture, was examined weekly by Mr. Swain for twelve months, the temperature varying from 57° to 58½° Fahr., it being lowest from the beginning of February to the middle of May, and highest in September and October to the middle of November. The experiments above mentioned were made in 1837 and 1838, and the results mentioned at the Birmingham meeting; but the Broad Oak pit having been increased in depth since that time, a thermometer was inserted in it, in a hole bored in metal as before. It was in a place 408 yards deep, and indicated a temperature of 61°, remaining nearly constant for twelve months. Mr. Fitzgerald being recently engaged in sinking a deep coal pit at Pendleton, two miles from Manchester, Mr. Hodgkinson conceived this to be a favourable opportunity for getting additional information on the subject of subterranean temperature; and, on his application to the proprietor, the engineer, Mr. Ray, readily made for him, during the sinking of the pit, and afterwards in the workings, the experiments of which the results are below.

At 418 yards from the surface, the temperature, in a hole from three to four feet deep bored in dry rock, was 66°; at 450 yards deep it was 67°, and at 480 yards it was 69°. In the workings, at 461 and 471 yards deep, it was in both cases 65°.

The mean temperature of the air at Manchester, according to Dr. Dalton's experiments, is 48° Fahr.; and as the pits above-mentioned are not very far from Manchester, the mean temperature of the earth at the surface of each of them, may be considered as 48°. With that supposition the distance sunk for each degree of Fahr. would be as below.

In the Rock pit		32 yards.	
„ Haydock coal pit		20 „	
„ Broad Oak do.	33·7	32·5 „	= mean.
„ „	31·4		
„ Pendleton do. (shaft)	23·2		
„	23·7	23·2 „	= mean.
„	22·8		
„ Do. (in workings)	27·1	27·4 „	= mean.
	27·7		

The mean from the whole being 27 yards for each degree of temperature.

On the Principles of Electro-Magnetical Machines. By Prof. JACOBI, *of St. Petersburgh.*

I have the honour to present to the British Association an historical sketch of the laws which regulate the action of electro-magnetic machines, laws which will enable us to determine in a precise manner the important question of the application of this remarkable force as a moving power. Since the commencement of my labours, which had partly a purely practical tendency, I proposed to myself to fill up as much as possible the blank which still remained in our knowledge of electro-magnetism. With the assistance of M. Lenz, I prosecuted the labours, which were the more arduous as they had but few precedents in the direction which I considered it necessary to follow, and we began to examine carefully the laws of electro-magnets. The report, which contains the results of our researches, was read in June 1838, before the Academy of Sciences at St. Petersburgh. I take the liberty of repeating here, very briefly, the contents of this first report. The problem which we sought to determine may be stated as follows: If a nucleus of malleable iron and a voltaic battery of a certain surface is given, into what number of elements should this surface be divided? what should be the thickness of the wire of the helix which surrounds the nucleus? and, lastly, what number of turns should this helix have, in order to produce the greatest amount of magnetism? I will not dilate here upon the manner in which we have proceeded, or upon the degree of certainty which belongs to the laws established according to our observations. I take the liberty of appending to this statement the report in question, and will proceed to explain the particular laws: 1st. The amount of magnetism engendered in malleable iron by galvanic currents is in proportion to the force of those currents. 2ndly. The thickness of the wire twisted into a helix, and surrounding a rod of iron, is absolutely of no consequence, provided that the helix have the same number of turns, and the current be of the same force. This law extends also to the case in which ribbons of copper were employed instead of wire. Nevertheless I must notice, that in order to obtain a current of equal force, it is necessary to employ a voltaic apparatus of greater force, if small wires which offer a greater resistance are employed. 3dly. If the current remain the same, the influence which the diameter of the helix exercises may be neglected in the majority of practical cases. 4thly. The total action of the electro-magnetic helix upon the rod of iron, is equal to the sum of the effects produced by each coil separately. Adopting these laws, and submitting them to calculation according to the formula of M. Ohm, the importance of which formula has but lately begun to be appreciated by some British philosophers, we have established the formula which contains all the particular conditions required to obtain the maximum amount of magnetism, which may be expressed in the following extremely simple manner, viz. *the maximum of magnetism is always obtained when the total resistance of the conducting wire, which forms the helix, is equal to the total resistance of the pile.* On referring to the remarkable law of the definite action

of the galvanic current, established by Mr. Faraday, it is found that the magnetism of malleable iron divided by the consumption of zinc, —a quantity which we have called economic effect—is with reference to the maximum of this magnetism, a constant, or an expression into which neither the thickness of the wire nor the number of the elements into which the total given surface of the battery is divided, enters, but only the total thickness of the envelope.

Having finished these first researches, and having obtained these results, which were highly satisfactory, not only for their simplicity, but also for their practical value, we set about extending our inquiries to iron rods of different dimensions. Is there, it may be asked, any specific effect produced by the length or thickness of the nucleus? or does the degree of magnetism solely depend upon the construction of the helix, and the force of the current? The solution of this new problem presents a greater difficulty than the problem which we had succeeded in completely solving. Now, we are obliged to take iron rods of different dimensions, and consequently, in all probability of different qualities. Similar conditions with reference to the action of the electro-magnetic helices are likewise difficult to obtain; and we soon perceived that these circumstances rendered it impossible to attain so close an accordance as that which we had obtained in our former observations. Although these experiments were made two years ago, the results have not yet been published, because, being occupied with other labours, we have not been able to find the necessary time for their reduction and arrangement, and for the requisite calculations. Nevertheless I take the liberty of presenting to the Section some results, which are not devoid of interest, and which are intimately connected with the question of electro-magnetic machines. We submitted nine cylinders of malleable iron, each eight inches in length, and of different diameters, from three inches down to one-third of an inch, to the action of a voltaic current of the same force in each case, and we obtained the amount of magnetic force represented in the following table:—

Diameter of the rods.	Magnetism observed.	Magnetism calculated.
3	447	442
$2\frac{1}{2}$	378	376
2	308	310
$1\frac{1}{2}$	246	244
1	175	178
$\frac{5}{6}$	158	156
$\frac{2}{3}$	142	135
$\frac{1}{2}$	112	113
$\frac{1}{3}$	87	91

This calculation has been made according to the formula $m = 131{\cdot}75\ d + 46{\cdot}75$, in which the constants have been obtained by the method of the least squares. The differences between calculation and observation are not so large that they cannot be attributed to the inevitable errors of observation, and to circumstances inherent in the

qualities of iron, &c. A similar agreement is found between other observations, which we shall describe in the report itself. I think, therefore, we may admit the following law, namely, that the *amount of magnetism received by different iron rods of the same length, and submitted to the influence of a current of the same force, is proportional to the diameter of the rods.* I must remark, that the constant which we have added in the formula depends upon the magnetic influence which the helix exercises, independently of the nucleus of iron which it encloses. The practical consequences which may be deduced from this remarkable law are of considerable importance. Among these, however, I will at present mention only the following. Having found that the amount of magnetism is proportional to the surface of the malleable iron, and taking into account the quantity of iron employed in the electro-magnets, it is ascertained that it is more advantageous to employ in the construction of electro-magnetic machines, rods of small instead of large dimensions; or rather hollow iron, in accordance with my own experiments of 1837, which are found in 'Taylor's Scientific Memoirs,' vol. ii. &c. I cannot pass over in silence the experiments of Prof. Barlow, who, as is well known, proved a long time before that the induction of the terrestrial magnetism upon malleable iron, depends only upon the surfaces, and is almost independent of the thickness. In order to ascertain the law of electro-magnets of different lengths, M. Lenz and I undertook numerous and laborious observations, which were extended even to rods of thirteen feet in length, and keeping in view at the same time the determination of the particular distribution of magnetism in the rods. Among these observations I shall only refer to such as seem most applicable to electro-magnetic machines, and which have yielded results as simple as unexpected. The following table contains the results of some observations made with rods of the same diameter, but of different lengths, covered with electro-magnetic helices, and influenced by a current of the same force. M being the magnetism of the extremities, and n the number of the coils of the helix, we have $\frac{M}{n} = x$, a formula according to which we may calculate the numbers contained in the third column. The numbers in the fourth column are deduced from a series of other observations, made with the same helix of 960 turns, which did not cover the whole length of the rods, but were collected at the extremities only, where they occupied a space of about two inches in length. The helices being the same in all the observations, it was only necessary to divide the magnetism of the extremities by 960, in order to find the numbers of this column.

Table of Experiments upon the Magnetic Forces of Rods of different lengths.

Length of the rods.	Number of coils.	Mean value of one coil, if the helix occupies the whole length.	Mean value of one coil, if the helix occupies only the extremities.
3′	946	7·334	7·560
2′·5	789	6·993	7·264
2	634	7·402	6·871
1·5	474	7·880	7·491
1	315	7·847	7·573
0·5	163	7·766	7·691
		7·537	7·408

From these numbers it will be seen that the influence of one coil of the helix is nearly the same for all the rods, and that their length does not exercise any specific influence. It is only in proportion to the number of the turns or revolutions, and to the force of the current, that the rods can acquire a greater or less amount of magnetism. The small rods even appear to have a slight advantage over large rods, since it has been found by experiments that the actual force of rods of three feet bears to that of rods of half a foot the ratio of seventy-three to seventy-seven. It is also found that there is a gain of seventy-five to seventy-four when the whole length of the rods is covered, instead of simply collecting the same number of coils around the extremities. The differences between the observations and the simple laws are, as will be judged, quite inconsiderable for practical purposes, and will, in time, I hope, entirely disappear by a complete integration embracing the whole length of the rods, and founded upon the effect of an elementary part of the current. I will now hasten on to the immediate object of my present address. In March 1839, M. Lenz and I presented to the Academy of Sciences at St. Petersburgh, a report, which I shall present to the Association. It contains the result of the experiments by which we have been enabled to establish the remarkable law, *that the attraction of the electro-magnets is proportional to the square of the force of the galvanic current, to the influence of which the rods of iron are submitted.* This law is of the highest practical importance, as it serves for the basis of the whole theory of electro-magnetic machines.

Before proceeding, I may be permitted to make some remarks concerning an instrument which I laid before the Academy of Sciences, in the commencement of this year. It is destined to regulate the galvanic current, and is of value in many investigations of this kind. During my sojourn in London, Prof. Wheatstone has shown me an instrument, founded on exactly the same principles as mine, and with very inconsiderable modifications and differences. Now, it is quite impossible that he should have had the least notice of my instrument; but as it is probable that its use may be greatly extended, I must add, that while I have only used this instrument for regulating the force of the

currents, he has founded upon it a new method of measuring these currents, and of determining the different elements or constants, which enter into the analytical expressions, and on which depends the action of any galvanic combination. It is principally to the measure of the electromotive force, by those means, that Mr. Wheatstone has directed his attention; and he has shown me, in his unpublished papers, very valuable results which he has obtained by this method.

While these purely theoretical researches were in progress, I did not fail myself to enter directly upon the question of the practical application of electro-magnetism. Unfortunately, I cannot here give the details either of the experiments which I have made upon a very large scale, or of the machines and apparatus of various kinds which I have constructed. The necessity of multiplying the facts or tangible results —a necessity the more urgent, because the practical applications of this force increased so very rapidly—this necessity, I say, has not allowed me time or leisure to digest and arrange them. I can only here express my readiness to afford any explanation of the details which may be desired. I will, however, particularly notice the satisfactory results of the experiments made last year with a boat of twenty-eight feet in length and seven and a half feet in width, drawing $2\frac{3}{4}$ feet of water, and carrying fourteen individuals, which was propelled upon the Neva at the rate of about three English miles in the hour. The machine, which occupied very little space, was set in motion by a battery of sixty-four pairs of platina plates, each having thirty-six square inches of surface, and charged according to the plan of Mr. Grove, with nitric and diluted sulphuric acid. Although these results may perhaps not satisfy the exaggerated expectations of some persons, it is to be remembered, that in the first year, namely, in 1838, this boat being put in motion by the same machine, and employing 320 pairs of plates, each of thirty-six square inches, and charged with sulphate of copper, only half this velocity was obtained. This enormous battery occupied considerable space, and the manipulation and the management of it was very troublesome. The judicious changes made in the distribution of the rods, in the construction of the commutator, and lastly, in the principles of the voltaic battery, have led to the successful result of the following year, 1839. We have gone thus on the Neva more than once, and during the whole day, partly with and partly against the stream, with a party of twelve or fourteen persons, and with a velocity not much less than that of the first invented steam-boat. I believe that more cannot be expected from a mechanical force, whose existence has only been known since 1834, when I made the first experiment at Königsberg, in Prussia, and only succeeded in lifting a weight of about twenty ounces, by even this electro-magnetic power.

I must, on the present occasion, confess frankly and without reserve, that hitherto the construction of electro-magnetic machines has been regulated in a great measure by mere trials; that even the machines constructed according to the indisputable laws established with regard to the statical effects of electro-magnets, have been found inefficient, as soon as we came to deal with motion. Being always

accustomed to proceed in a legitimate manner, and feeling great regret at the irregular attempts which were being made everywhere, without any scientific foundation, this state of things appeared to me so unsatisfactory, that I could not but direct all my efforts to ascertain clearly the laws of these remarkable machines. I submit the formulæ relative to these laws, which appear to me to recommend themselves as much by their simplicity as by the natural manner in which they develope themselves. Let R represent all the mechanical resistances acting upon the machine, and v the uniform velocity with which it moves: we have for the power or mechanical effect, the expression $T = R\,v$. Let n be the number of the coils of the helix which covers the rods; z, the number of the plates of the battery; B, the total resistance of the galvanic circuit; E, the electromotive force; k, a coefficient, which depends on the arrangement of the bars, the distance of the poles, and the quality of the iron; we have then for the maximum of the mechanical effect which will be obtained, the expression—

$$\text{I.} \quad T_m = \frac{z^2 E^2}{4\,B\,k}.$$

For the velocity, which corresponds to this maximum,

$$\text{II.} \quad v = \frac{B}{k\,n^2}.$$

For the resistance acting upon the machine,

$$\text{III.} \quad R = \frac{n^2 z^2 E^2}{4\,B^2}.$$

Lastly, for the œconomic effect, *i.e.* the duty or the mechanical effect divided by the consumption of zinc in a given time,

$$\text{IV.} \quad O = \frac{E}{2\,k}.$$

These formulæ may be expressed in the terms:—

1st, The maximum of mechanical effect which may be obtained from a machine, is proportional to the square of the number of voltaic elements, multiplied by the square of the electromotive force, and divided by the total resistance of the voltaic circuit. There enters, moreover, into the formula, a factor, which I have designated k, and which depends upon the quality of the iron, the form and disposition of the rods, and the distance between their extremities. The result is, that with reference to some other investigations, which I have made of voltaic combinations, and under similar conditions, the use of platinum, zinc, the resistance being the same, will produce an effect two or three times greater than the use of copper, zinc.

2nd, Neither the number of the coils of the helix which covers the rods, nor the diameter or the length of the rods themselves, has any influence upon the maximum of the power. It results, therefore, that neither by adding to the length or diameter of the rods, nor by employing a greater quantity of wire, can the power be increased. There is,

however, this remarkable fact, that the number of coils disappears from the formula, simply because the force of the machine is in a direct ratio, and the velocity is in an inverse ratio, to the square of this number. It is thus that the number of coils, the dimensions of the rods, and the other constituent parts of an electro-magnetic machine, should be considered simply as occupying the range of the ordinary mechanisms which serve for the transmission or transformation of the velocity, without increasing the available power. So it would be possible to use, instead of the ordinary wheelwork, rods of greater or less length, or a greater or less quantity of wire, in order to establish between the force and the velocity, the relation which the applications to manufacturing processes may require.

3rd, The mean attraction of the magnetic rods, or the pressure which the machine can exert, is proportional to the square of the current. This pressure is indicated by the galvanometer, which in this manner performs the function of the manometer of steam-engines.

4th, The economic effect, *i. e.* the duty or the available power, divided by the consumption of zinc, is a constant quantity, which is expressed most simply by the relation between the electromotive force and the factor k, which has been previously noticed. I may here repeat, what I stated elsewhere, that by employing platinum instead of copper, the theoretical expenses may be reduced in the proportion of nearly 23 to 14.

5th, The consumption of zinc, which takes place while the machine is at rest, and does not work at all, is double that which takes place while it is producing the maximum of power.

I consider that there will not be much difficulty in determining with sufficient precision the duty of one pound of zinc, by its transformation into the sulphate, in the same manner that in the steam-engine, the duty of one bushel of coal serves as a measure to estimate the effect of different combinations. The future use and application of electro-magnetic machines appears to me quite certain, especially as the mere trials and vague ideas which have hitherto prevailed in the construction of these machines, have now at length yielded to the precise and definite laws which are conformable to the general laws which nature is accustomed to observe with strictness, whenever the question of effects and their causes arises. In viewing on the one hand a chemical effect, and on the other a mechanical effect, the intermediate term scarcely presents itself at first. In the present case, it is magneto-electricity, the admirable discovery of Faraday, which we should consider as the regulating power, or, as it may be styled, the logic of electro-magnetic machines.

On the Theory of Electricity. By C. J. Kennedy.

The author shows in the commencement of his paper, that on the theory of a single fluid, the electrified aërial current proceeding from the positive wire must be superior in force to the electrified aërial current proceeding from the negative wire. He describes various ex-

periments with light wheels, and suspended gold leaf, in which this appears to be a fact. He adverts to other *experimenta crucis*, all concurring in his opinion to establish the theory of a single electric fluid, as the movement of a line of water, or saline solution, from the positive or vitreous to the negative or resinous pole, as found by Mr. Porret and M. de la Rive; and appeals to ordinary experiments in which cards are perforated by electrical discharge in confirmation of the same view. The theory of a single electric fluid is capable of assuming two forms, in which material idio-repulsion is entirely discarded. The one form is that of an original theory adopted by Mr. Kennedy in the year 1825. It was deduced from a rather complicated fluxionary calculation, by which a beautifully simple result was obtained. An exponential fluxionary equation, involving all the possible powers and simple functions of the electric force, was employed. The result of the calculation was surprisingly simple, namely, that electrical action varies in the inverse ratio of the electric quantity; or, $A \propto \frac{1}{q}$. Let A' represent the attraction of a material corpuscle for electricity, in any given electrical condition, suppose the neutral state, and q the quantity of electricity which that corpuscle then contains. The tendency of two material corpuscles $c\,c'$ towards each other, may be denoted by T, and is $= 2\,A'q = A' \times q + A' \times q$. Now, if the electrical quantities of c and c' become each $= x$, the attraction of each of these corpuscles for electricity will become $= \frac{A'\,q}{x}$, and T will become $= \frac{A'\,q}{x} \times x + \frac{A'\,q}{x} = 2\,A'\,q$, as before; that is, the joint tendency of the two corpuscles to mutual approach remains unaltered, so long as their electrical quantities are equal to each other, whatever each of these electrical quantities may be, whether a large quantity or a small. Suppose next, that the electrical quantity of c becomes $= x$, and that of $c' = y$, then their respective attractions for electricity will be $\frac{A'\,q}{x}$ and $\frac{A'\,q}{y}$; and T will be $= \frac{A'\,q}{x} \times y + \frac{A'\,q\,x}{y}$, or $\frac{A'\,q\,y}{x} + \frac{A'\,q\,x}{y}$. Now this must be greater than $2\,A'\,q$, in every case in which x is unequal to y; for if x is unequal to y—because A' and q are constant quantities— $\frac{A'\,q\,y}{x}$ must be unequal to $\frac{A'\,q\,x}{y}$. If x be greater than y, $\frac{A'\,q\,x}{y}$ must be greater than $\frac{A'\,q\,y}{x}$. Now $\frac{A'\,q\,y}{x} : A'\,q :: A'\,q : \frac{A'\,q\,x}{y}$. Whence,* $\frac{A'\,q\,y}{x} + \frac{A'\,q\,x}{y}$ are greater than $2\,A'\,q$; that is, the least possible value of T is $2\,A'\,q$;—in common language, the tendency of the two corpuscles to mutual

* Euclid's Elements, Book v. prop. xxv.

approach, is the least possible when they contain equal quantities of electricity. It follows also, that the more unequal x and y are, the greater must the sum of $\frac{A' q y}{x}$ and $\frac{A' q x}{y}$ be; that is, the more the electrical quantities of the two corpuscles differ, the greater is their tendency to mutual approach. The phænomena of electrical attraction, repulsion, and quiescence, may be explained on this theory, in a manner perfectly satisfactory, and exceedingly easy.

The author then exemplified this in the following cases:

1. Quiescence.

Case 1.—*Let A B C D be four small balls, equal to each other, homogeneous, equidistant in the same straight line, and all in the neutral electrical state.*

Case 2.—*Let A be electrified plus, while C B D remain in the neutral state.*

Case 3.—*Let A be electrified minus, while B remains in the neutral state.*

2. Attraction.

Let A be positively, and B negatively, electrified.

3. Refulsion.

Case 1.—*Let A and B be alike electrified plus.*

Case 2.—*Let A and B be alike electrified minus.*

An Account of the Magnetic Observatory of Munich. By Dr. Lamont.

The author stated that the building had been undertaken in April this year, and that the regular series of observations, comprehending both the daily observations from two to three hours, and the term-day observations, was commenced on the 1st of August. The Magnetic Observatory of Munich differs in two respects from other establishments of the same kind. In the first place, it is not a magnetical *house*, but a subterraneous building, which is situated to the S.W. of the Royal Observatory, and at a distance of about 120 feet, and connected with it by a subterraneous passage. The depth of the magnetic observatory below the surface of the earth is 13 feet, thus affording the advantage of a temperature nearly equal at all times of the year, and rendering the corrections applied to magnetic observations in order to reduce them to a fixed temperature—corrections which are in general subject to considerable uncertainty—if not unnecessary, at least sufficiently small to be determined with the utmost degree of accuracy. In the second place, the instruments are of greater dimensions than those usually employed in magnetic observatories, and may be considered as sufficient in all respects for the most delicate investigations. The magnetic bars weigh 25lbs. each; the theodolite has a circle of $2\frac{1}{2}$ feet dia-

meter, and an achromatic telescope of $3\frac{1}{2}$ inches aperture. It may be remarked that the horizontal-force instrument differs from the bifilar magnetometer, the force that holds the bar in a direction perpendicular to the magnetic meridian being a spiral spring. Besides the instruments fixed in the observatory, there are portable instruments for making experiments with bars of $\frac{1}{2}$lb., 1lb., 4lbs., 10lbs. and 25lbs.

The munificence with which the king of Bavaria has been always known to support the cause of science, and the liberality of the Crown Prince, who takes peculiar interest in physical researches, have contributed to render the magnetic observatory of Munich the most complete establishment of this kind on the continent.

A general statement of the System of Meteorological Observations carried on in Bavaria. By Dr. LAMONT.

The Royal Observatory of Munich constitutes the central establishment, and has the superintendence of all meteorological observations made under public authority. There are meteorological observatories at Ratisbon, Augsburg, and Hohen-Peissenberg, the latter being situated on the summit of a mountain 3000 feet above the level of the sea. Besides, meteorological observations are registered partly by members of the Royal Meteorological Society, partly by persons appointed by Government, at 260 towns and villages in Bavaria. The observations thus obtained, though not equally complete, some of them being registered only once, some twice, and but a comparatively small number three times a day, will be found extremely valuable for the purposes of meteorology. Hourly observations of the barometer and thermometer have been made at the Royal Observatory of Munich since May 1838, by means of accurate registering instruments, constructed on a new principle. Dr. Lamont, in mentioning this extensive system of observations, referred for the results and further particulars to the annual publications of the Royal Observatory of Munich. He concluded by remarking, that the great object of meteorology was to find the causes from which the changes in the atmosphere arise; to trace the propagation of these changes from one place to another, and the modifications they undergo on their way; and to show what relation exists between the states of the atmosphere at different parts of the globe, and how the changes at one place depend upon, or are connected with, simultaneous or preceding changes at another. This, he said, can only be attained by combining observations made in different countries after a general and uniform system; and in mentioning at that meeting the extensive observations carried on in Bavaria, it was his intention to show how far a general system, such as had been just alluded to, was likely to be supported in that part of Germany, and to express the hope that such a general system will be introduced at no distant period, perhaps, by the same Association by whose exertions a similar system of magnetic observations has now so successfully been carried into effect.

Notice accompanying a Series of Meteorological Observations made at Trevandrum. By Mr. Caldecott.

The author commenced with observing, that having had an opportunity in India of forwarding an inquiry which the British Association has considered to possess great interest, viz. that into the thermometrical, barometrical, and hygrometrical condition of the atmosphere within the tropics, it was with feelings of great pride and pleasure that he was enabled, by his present visit to this country, to present to the meeting a series of hourly observations of the thermometer, barometer, and moistened bulb thermometer, carried on under his direction and superintendence, at a situation only $8\frac{1}{2}^{\circ}$ north of the equator.

The author then proceeded to describe the circumstances under which the observations were instituted in the following terms:—"In the beginning of the year 1837 it devolved on me to undertake the direction of an observatory then recently established at Trevandrum in the south of India, by His Highness the Rajah of Travancore, (a young native prince of that country, of whom, for his liberal patronage of science, his munificent encouragement of education among his subjects, and above all for his beneficent rule, it is impossible to speak too highly) and noticing among the recommendations promulgated by the British Association, that a set of hourly meteorological observations within the tropics was considered highly desirable, I thought the opportunity a good one for supplying this desideratum. I accordingly explained the matter to His Highness, and with the liberal confidence which I have always experienced from him, was immediately provided with the necessary means for accomplishing my purpose; I have therefore no other merit to claim (with respect to these observations) than that of a diligent perseverance in the task I had imposed on myself."

Mr. Caldecott then described minutely the building in which the observations were made, the instruments used, and the registers which accompany his communication; these observations have been made every hour since the commencement of June, 1837, are still in progress, and are intended to be extended to a period of five years from their commencement. The situation is described to be in latitude $8^{\circ}\ 30'\ 35$ north, longitude $5^{h}\ 8^{m}$ east of Greenwich, 170 feet above the level of the sea, and distant from it in a direct line about 2 miles.

Every precaution was taken to ensure accuracy; and of the observers (all natives of India), Mr. Caldecott remarks, that "after the first difficulty of instructing them is surmounted, their patient, diligent, and temperate habits peculiarly fit them for the office here required of them, and I have always found those who have been selected for the duty fully as trustworthy as, I imagine, is any class of persons to whom such observations are usually entrusted."

The registers are arranged in monthly tables, and contain, among other determinations, the following particulars clearly shown, and ready for any investigation to which they may be considered applicable; viz.

1st, in "Temperature."

1. The mean of each hour for the month.

2. The mean of each day of the month.
3. The same two means for each period of ten days.
4. The mean range for the month, and for each ten days; the extreme range, &c.

2nd, in "Pressure."

1. The pressure of each hour for the month.
2. The mean pressure of each day of the month.
3. The same two means for each period of ten days,
4. The maximum and minimum pressure of each day, with the extreme variation for each day; the maximum and minimum pressure of the month, with the extreme variation for the month, &c.
5. The four semi-oscillations for each 24 hours, with the mean values of them for the month.

3rd, in "Humidity."

1. The temperature of the air each hour (repeated from the register of temperature).
2. The depression of the wet-bulb thermometer for ditto.
3. The dew-point for each hour, calculated from Professor Apjohn's formula, disregarding his correction for pressure.
4. The mean of all these for each day.
5. The quantity of rain for each twelve hours.

Besides these monthly registers, the author exhibited two tables drawn up in the form first adopted by Sir David Brewster, showing for the complete year of the observations, viz. from June 1837 to June 1838,

1st, The daily and monthly mean temperature. 2nd, The mean temperature of each hour for each month, and for the whole twelve months.	from 8760 observations.

Also two other tables, showing for the same period,

1st, The daily and monthly dew-points. 2nd, The mean dew-point of each hour for each month, and for the whole twelve months.	ditto.

The first two tables give for the mean temperature of the station $78^{\circ}\cdot89$, and the other two give for the mean dew-point $71^{\circ}\cdot78$.

The barometric registers give by a mean of all the diurnal semi-oscillations for the same period the following results:

Fall between	10 A.M. and	4 P.M.	0·109 inch.
Rise	4 P.M.	10 P.M.	0·108
Fall	10 P.M.	4 A.M.	0·071
Rise	4 A.M.	10 A.M.	0·073

Times of maxima between the hours of 9 and 10 morning and evening.
Times of minima between those of 3 and 4 afternoon and morning.

Mr. Caldecott concluded his communication by noticing that he was about to return to his post in India amply furnished with meteorological, magnetical, and astronomical instruments, and added that, should the committee of the Physical Section of the British Association see fit to honour him with any suggestions as to points in meteorology, or any other branch of the physical sciences which his local situation

and means might enable him to elucidate, or be of any use in, he would feel proud to receive its instructions, and would do all in his power to forward its objects.

Note.—At the meeting of the General Committee on the 24th Sept., a committee was appointed to consider the propriety of printing, *in extenso*, the hourly meteorological observations communicated by Mr. Caldecott, together with those made at Plymouth by Mr. Snow Harris, at the instance of the British Association.

On Storms. By JAMES P. ESPY.

Mr. Espy commenced by stating, that he had found, by examining simultaneous observations in the middle of storms, and all round their borders, that the wind blows inward on all sides of a storm towards its central parts, towards a point if the storm is round, and towards a line if the storm is oblong, extending through its longest diameter. He had been able to investigate within the last five years seventeen storms, without discovering one exception to the general rule. As an example of recent date, he described and illustrated by a map the course of the wind in Great Britain on the night of the 6th of January, 1839, between the hours of 10 and 12. The observations were thus stated:

1. Romney—strong at 8 p.m., S.E.
2. Thwaite—strong from 10 to 12, S.S.E.
3. Southwold—the *Susannah* driven on shore at 8 p.m., by a south-east wind.
4. Birmingham—wind strong, E. of south, till one in the morning.
5. Manchester—S.E. till 12 at night.
6. Leeds—ditto ditto.
7. Bridlington—got round S.E. in night, and continued so, blowing a gale till after midnight.
8. Whitby—at $10\frac{1}{2}$ p.m. S. by E., high wind.
9. Berwick—changed from E. of south to S.W., at 10 p.m.
10. Dundee—on the night of the 6th and day of the 7th, N.W.
11. Montrose—all night of 6th and 7th a hurricane, N.W.
12. Aberdeen—ditto ditto.
13. Cape Wrath—all 6th and 7th, N.W.
14. Scowrie—evening of 6th till 12 at night, N.W.
15. Isle of Glan—at 11 p.m., N.W.
16. Lismore—night of 6th, N.W. to N.
17. Corsewell—6 p.m. till 12, S.W.
18. Strangford, Ireland—at 12, night of 6th, S.W.
19. Mull of Galloway—south till $1^{h}\ 30^{m}$ a.m., of 7th.
20. Calf of Man—S.S.W. till midnight.
21. Liverpool—changed from S.S.E. after 10.
22. Plymouth—S.W. till 12 at night of 6th.

From this, and from documents which Mr. Espy proceeded to read, it appeared that during those hours the wind was blowing a violent gale on the north-western part of the island from the north-west, on the south-western parts from the south-west, and on the south-eastern parts a strong gale from the south-east and south-south-east; and that

in the middle parts of the island it changed from south-easterly to south-westerly about those same hours—the change taking place about two hours sooner on the west side of the island than on the east side in the central parts, but much sooner in the northern parts than in the southern. The barometer also fell sooner in the northern and western parts than in the southern and eastern. From these two circumstances he thinks it highly probable that this storm moved not exactly towards the east, but a little south of east, and if so, it would be similar to some storms which he had examined in the United States.

The barometer was at its minimum at Cape Wrath, in the north-west corner of Scotland, two hours and a half sooner than at the Calf of Man, five hours sooner than at Edinburgh, and thirteen hours and a half sooner than at Thwaite, in Suffolk. Mr. Espy then stated that he had examined the data furnished by Col. Reid, of several hurricanes in the West Indies, and found conclusive evidence that the wind blew inwards to a central space in all these storms. Diagrams of two were exhibited: one on the 3rd of October, 1780, in which Savannah-la-Mar was destroyed. In that storm, at its very height, the wind at Savannah-la-Mar, on the south side of the island of Jamaica, was south,—and nearly opposite to that point, on the north side of the island, the wind was north-east, or nearly in an opposite direction, for two hours at the time of the greatest violence of the storm at both places. The other storm was on the 18th of August, 1837, off Charleston, south-east. On that day, the ship *Duke of Manchester* had the centre of the storm passing over her, and, on the same day, the *West Indian* and the *Rawlins,* which were on the south-west of the *Duke of Manchester*, had the wind all day from 2 a.m. south-west, and at the same time the *Cicero* and the *Yolof*, on the north-east of the *Duke of Manchester*, had the wind north-east and east-north-east, the *Yolof* all day, till 8 p.m.

Mr. Espy then stated that he had visited the tracks of eighteen tornadoes, and examined several of them with great care, and found that all the phænomena told one tale—the inward motion of the air to the centre of the inverted cone of cloud as it passed along the surface of the earth. From all these facts he inferred that there is an inward motion of the air towards the centre of storms from all sides; and stated that this inference ought to be drawn from the well-known fact, that the barometer stands lower in the midst of a storm than it does all round its borders.

Mr. Espy exhibited an instrument, which he called a Nephelescope, which enabled him to measure the expansion of air with great accuracy, and he found it to agree with calculations made on chemical principles. He then proceeded to give an outline of his theory, premising that the numbers he should introduce were not intended to be strictly accurate, and would be subject to many corrections,—one in particular, in which no notice had been taken of the specific heat of air under different pressures. The following are extracts.

"When the air near the surface of the earth becomes more heated or more highly charged with aqueous vapour, which is only five-eighths

of the specific gravity of atmospheric air, its equilibrium is unstable, and up-moving columns or streams will be formed. As these columns rise, their upper parts will come under less pressure, and the air will therefore expand; as it expands, it will grow colder about one degree and a quarter for every hundred yards of its ascent, as is demonstrated by experiments with the Nephelescope. The ascending columns will carry up with them the aqueous vapour which they contain, and, if they rise high enough, the cold produced by expansion from diminished pressure will condense some of this vapour into cloud; for it is known that cloud is formed in the receiver of an air-pump when the air is suddenly withdrawn. The distance or height to which the air will have to ascend before it will become cold enough to begin to form cloud, is a variable quantity, depending on the number of degrees which the dew-point is below the temperature of the air; and this height may be known at any time by observing how many degrees a thin metallic tumbler of water must be cooled down below the temperature of the air before the vapour begins to condense on the outside. The difference between the dew-point and the temperature of the air in degrees is called (by Mr. Espy) the complement of the dew-point*.

"As the temperature of the air sinks about one degree and a quarter for every hundred yards of ascent, and the dew-point sinks about a quarter of a degree, it follows that as soon as the column rises as many hundred yards as the complement of the dew-point contains degrees of Fahrenheit, cloud will begin to form; or, in other words, the bases of all clouds forming by the cold of diminished pressure from up-moving columns of air, will be about as many hundred yards high as the dew-point in degrees is below the temperature of the air at the time. If the temperature of the ascending column should be ten degrees above that of the air through which it passes, and should rise to the height of 4800 feet before it begins to form cloud, the whole column would then be 100 feet of air lighter than surrounding columns; and if the column should be very narrow, its velocity of upward motion would follow the laws of spouting fluids, which would be eight times the square root of 100 feet a second, that is, 80 feet a second, and the barometer in the centre of the column at its base would fall about the ninth of an inch. As soon as cloud begins to form, the caloric of elasticity of the vapour or steam is given out into the air in contact with the little particles of water formed by the condensation of the vapour. This will prevent the air in its further progress upwards from cooling so fast as it did up to that point; and, from experiments with the Nephelescope, it is found to cool only about one-half as much above the base of the cloud as below; that is, about five-eighths of a degree for one hundred yards of ascent, when the dew-point is about

* The height of the bases of forming cumuli may be ascertained by the following empirical formula: $103\left(\frac{t-t'}{t'}\right)$ = height of base in 100 yards; t being the temperature of the air in degrees of Fahrenheit, and t' the temperature of the wet bulb *swung briskly in the air.*

70°. If the dew-point is higher, it cools a little less, and if the dew-point is lower, it cools a little more, than five-eighths of a degree in ascending one hundred yards.

"Now it has been ascertained by aëronauts and travellers on mountains, that the atmosphere itself is about one degree colder for every hundred yards in height above the surface of the sea; therefore, as the air in the cloud above its base is only five-eighths of a degree colder for every hundred yards in height, it follows, that when the cloud is of great perpendicular height above its base, its top must be much warmer than the atmosphere at that height, and consequently much lighter. Indeed, the specific gravity of a cloud of any height, compared to that of the surrounding air at the same elevation, may be calculated, when the dew-point is given; for its temperature is known by experiments with the Nephelescope, and the quantity of vapour condensed by the cold of diminished pressure at every point in its upward motion, and of course the quantity of caloric of elasticity given out by this condensation is known, and also the effect this caloric has in expanding the air receiving it, beyond the volume it would have if no caloric of elasticity was evolved in the condensation of the vapour. For example, according to the experiments of Prof. W. R. Johnson, of Philadelphia, a pound of steam, at the temperature of 212°, contains 1030° of caloric of elasticity; and if the sum of the latent and sensible caloric of steam is the same at all temperatures, it follows, that a pound of steam being condensed in 1210 pounds of water at 32° would heat this water up one degree; and, as the specific caloric of air is only 0·267, if a pound of vapour should be condensed in 1210 pounds of air, it would heat that air nearly 4°, or, which is the same thing, it would heat 100 pounds of air about 45°. And in all these cases it would expand the air about 8000 times the bulk of water generated; that is, 8000 cubic feet for every cubic foot of water formed out of the condensed vapour. And as it requires between 1300 and 1400 cubic feet of vapour, at the ordinary temperatures of the atmosphere, to make one cubic foot of water—if this quantity be subtracted from 8000 it will leave upwards of 6600 cubic feet of actual expansion of the air in the cloud for every cubic foot of water generated there by condensed vapour.

"This great expansion of the air in the forming cloud will cause the air to spread outwards in all directions above, causing the barometer to rise on the outside of the cloud, above the mean, and to fall below the mean under the middle of the cloud as much as it is known to do in the midst of great storms. For example, if the dew-point should be very high, say 78°, then the quantity of vapour in the air would be about one-fiftieth of its whole weight; and if the up-moving column should rise high enough to condense one-half its vapour into cloud, it would heat the air containing it 45°, and the air so heated would occupy $\frac{45}{448}$ more space than it would be if it was not so heated. And if we assume a case within the bounds of nature, and suppose the cloud and the column under the cloud to occupy three-fourths of the whole weight of the atmosphere, or, in other words, if we suppose the top

of the cloud to reach a height where the barometer would stand at $7\frac{1}{2}$ inches, and the mean temperature of the whole column 40° warmer than the surrounding air, then would the barometer fall under the cloud at the surface of the earth, $\frac{40}{443}$ of 22·5, or a little more than 2 inches.

"Though the air may be driven up by the ascending column much higher than the point assumed in the last article, the cloud will cease to form at greater heights, because the dew-point, at these great elevations, falls by a further ascent as rapidly as the temperature—and at greater elevations, it will even fall more rapidly. If, for instance, the air should rise from where the barometer stands at 6 inches to where it stands at 3 inches, the dew-point would fall about 20°, but the temperature would fall less than 20°, and therefore no vapour would be condensed by such ascent.

"When a cloud begins to form from an ascending column of air, it will be seen to swell out at the top while its base continues on the same level, for the air has to rise to the same height before it becomes cold enough, by diminished pressure, to begin to condense its vapour into water; this will cause the base to be flat, even after the cloud has acquired great perpendicular height, and assumed the form of a sugarloaf. Other clouds also for many miles around, formed by other ascending columns, will assume similar appearances, and will moreover have their bases all on the same or nearly the same horizontal level; and the height of these bases from the surface of the earth, will be the greatest about 3 o'clock, when the dew-point and temperature of the air are the greatest distance apart. The outspreading of the air in the upper parts of an ascending column will form an annulus all round the cloud, under which the barometer will stand above the mean; of course the air will descend in the annulus, and increase the velocity of the wind at the surface of the earth, towards the centre of the ascending column, while all round on the outside of the annulus there will be a gentle wind outwards. Any general currents of air, which may exist at the time, will of course modify these motions, from the oblique forces they would occasion. The up-moving current of air must of course be entirely supplied by the air within the annulus, and that which descends in the annulus itself. The rapid disturbance of equilibrium, which is produced by *one* ascending column, will tend to form *others* in its neighbourhood; for the air being pressed outwards from the annulus, or at least retarded on the windward side, will form other ascending columns, and these will form other annuli, and so the process will be continued. These ascending columns will have a tendency to approach, and finally unite; for the air between them must descend, and in descending the temperature of the whole column will increase, for it is known that the air, at great elevations, contains more caloric to the pound than the air near the surface of the earth, because it is the upper regions that receive the caloric of elasticity, given out in the condensation of vapour into clouds. Therefore, when the air has descended some time in the middle, between two ascending columns, the barometer will fall a little, or at least not stand so high above the

mean as it does on the outside of the two clouds, and so the columns will be pressed towards each other. If one of two neighbouring columns should be greatly higher than the other, its annulus may overlap the smaller one, and of course the current under the smaller cloud will be inverted, and the cloud which may have been formed over the column thus forced to descend will soon disappear; for as it is forced downwards by the overlapping annulus of the more lofty column, it will come under great pressure, and its temperature will be thus increased; and it is manifest, that as soon as its top descends as low as its base, it will have entirely disappeared; and in the mean time the larger cloud will have greatly increased.

"As the air above the cloud formed by an ascending column is forced upwards, if it contains much aqueous vapour, a thin film of cloud will be formed in it by the cold of diminished pressure, entirely distinct from the great dense cumulus below; but as the cumulus rises faster than the air above it (for some of the air will roll off), the thin film and the top of the cumulus will come in contact; and sometimes a second film or cap may be formed in the same way, and perhaps a third and fourth. When these caps form, there will probably be rain, as their formation indicates a high degree of saturation in the upper air.

"When the complement of the dew-point is very great (twenty degrees and more), clouds can scarcely form; for up-moving columns will generally either come to an equilibrium with the surrounding air, or be dispersed before they rise twenty hundred yards, which they must do in this case before they form clouds. Sometimes, however, masses of air will rise high enough to form clouds; but they are generally detached from any up-moving column underneath, and of course cannot then form cumuli with flat bases; such clouds will be seen to dissolve as soon as they form, and even while forming they will generally appear ragged, thin, and irregular. Moreover, if the ground should be colder during the day than the air in contact with it, as sometimes happens after a continuance of very cold weather, then as the air touching the cold earth will be colder than the stratum above it, ascending columns cannot exist, and of course no cumuli can be formed on that day, even though the air may be saturated with vapour to such a degree as to condense a portion of it on cold bodies at the surface of the earth. Neither can clouds form of any great size, when there are cross currents of air sufficiently strong to break in two an ascending current, for the ascensional power of the up-moving current will thus be weakened and destroyed. This is one means contrived by nature to prevent up-moving columns from always increasing until rain would follow. Without some such contrivance it is probable that every up-moving column which should begin to form cloud when the dew-point is favourable, would produce rain; for as soon as cloud forms, the up-moving power is rapidly increased by the evolution of the caloric of elasticity."

Among the consequences of his theory, Mr. Espy describes in what manner it happens that rain does not fall on the leeward side of very

lofty mountains; and under what circumstances appear what are called tornadoes on land and waterspouts at sea.

"On visiting the path of a tornado, the trees on the extreme borders will all be found prostrated with their tops inwards, either inwards and backwards, or inwards and forwards, or exactly transverse to the path. The trees in the centre of the path will be thrown either backwards or forwards, or parallel to the path; and invariably if one tree lies across another, the one which is thrown backwards is underneath. Those materials on the sides which are moved from their places and rolled along the ground, leaving a trace of their motion, will move in a curve convex behind; those which were on the left hand of the path will make a curve from left hand to right, and those on the left hand of the path will make a curve from right hand to left; and many of these materials will be found on the opposite side of the path from that on which they stood on the approach of the tornado. Also those bodies which are carried up will appear to whirl, unless they arise from the very centre—those that are taken up on the right of the centre will whirl in a spiral from left to right, and those on the left of the centre will whirl in a spiral upwards from right to left. On examining the trees which stand near the borders of the path, it will be found that many of the limbs are twisted round the trees, and broken in such a manner as to remain twisted, those on the right-hand side of the path from left to right, and those on the left-hand side of the path from right to left. However, it will be found that only those limbs which grew on the side of the tree most distant from the path of the tornado are broken; for these alone were subject to a transverse strain. The houses which stood near the middle of the path will be very liable to have the roof blown up, and many of the walls will be prostrated, all outwards, by the explosive influence of the air within, and those houses covered with zinc or tin, from being air-tight, will suffer most. The floors from the cellars will also frequently be thrown up, and the corks of empty bottles exploded. All round the tornado, at a short distance, probably not more than three or four hundred yards, there will be a dead calm, on account of the annulus formed by the rapid efflux of air above, from the centre of the up-moving and expanding column. In this annulus the air will be depressed, and all round on the outside of it, at the surface of the earth, there will be a gentle wind outwards, and of course all the air which feeds the tornado is supplied from within the annulus. Nor is this difficult to understand, when the depression of the air in the annulus is considered, for any amount may be thus supplied by a great depression. Light bodies, such as shingles, branches of trees, and drops of rain or water formed in the cloud, will be carried up to a great height, before they are permitted to fall to the earth; for though they may frequently be thrown outwards above, and may then descend to a considerable distance at the side, they will meet with an in-blowing current below, which will force them back to the centre of the up-moving current, and so they will be carried aloft again.

"The drops of rain, however, will frequently be carried high enough to freeze them, especially if they are thrown out above so far as to fall

into clear air, for this air will in some cases be thirty or forty degrees colder than the air in the cloud. In this case, if the up-moving column is perpendicular, the hail will be thrown out on both sides; and on examination it will be found that two veins of hail fall simultaneously, at no great distance apart. It is indeed probable, that in all violent thunder-storms in which hail falls, the up-moving current is so violent as to carry drops of rain to a great height, when they freeze and become hail. It is difficult, if not impossible, to conceive any other way in which hail can be formed in the summer, or in the torrid zone. In those countries in which an upper current of air prevails in a particular direction, the tornadoes and waterspouts will generally move in the same direction, because the up-moving column of air in this meteor rises far into this upper current, and of course its upper part will be pressed in this direction; as the great tornado cloud moves on in the direction of the upper current, the air at the surface of the earth will be pressed up into it by the superior weight of the surrounding air. It is for this reason that the tornado in Pennsylvania generally moves towards the eastward.

"If a tornado should stop its motion for a few seconds, as it might do, on meeting with a mountain, it would be likely to pour down an immense flood of water or ice, in a very small space, for the drops which would be carried up by the ascending current would soon accumulate to such a degree as to force their way back, and this they could not do without collecting into one united stream of immense length and weight; and of course on reaching the side of the mountain, this stream, whether it consisted of water or hail, would cut down into the side of the mountain a deep hole, and make a gully all the way to the bottom of the mountain, from the place where it first struck.

"As the air spreads out more rapidly above than it runs in below, there will be a tendency in storms to increase in diameter, and this tendency will be greater on the north side than on any other, for the air in its efflux above finds less resistance on that side, for a reason assigned in the next paragraph; therefore it is probable that storms become elongated north and south, and then, if they move towards the east, they must travel side foremost.

"At the equator, or at least those parts of it where the trade-winds are constant from east to west, it is probable tornadoes travel from east to west. For as the air in the torrid zone is about 80° in temperature at a mean, and the air in the frigid zone is about zero, the air in the torrid zone is constantly expanded by heat about $\frac{80}{448}$ of its whole bulk in the frigid zone. This will cause the air at the equator to stand more than seven miles higher from the surface of the earth to the top of the atmosphere than at the north pole. The air therefore will roll off from the torrid zone both ways towards the poles, causing the barometer to fall in low latitudes, and rise above the mean in high latitudes. This will cause the air to run in below towards the equator, and of course rise there. Now from the principle of the conservation of areas, it will fall more and more to the west as it rises, and of course the upper current of the air, at the equator, probably moves

towards the west. However, as the air rolls off above, towards the north, it will be constantly passing over portions of the earth's surface, which have a less diurnal velocity than the part from which it set out; and as from the nature of inertia it still inclines to retain the diurnal velocity towards the east, which it originally possessed, when it reaches the latitude of about 20 or 25 degrees, it will then probably be moving nearly towards the north, and beyond that latitude its motion will be north-easterly.

"If violent storm clouds, which necessarily rise to a great height into the upper current, are driven forward in the direction of the upper current, it is probable that the barometer will rise higher in that part of the annulus which is in front of the storm, than in the rear, and if so, a sudden rise of the barometer, in particular localities, may become, when properly understood, one of the first symptoms of an approaching storm. In consequence of the high barometer in front of the storm in a semiannulus, the air will be forced downwards there, and cause, in some cases, a more violent action of the air or wind backwards, meeting the approaching storm, than will be experienced in the rear of the storm. As the barometer will probably be highest in the centre of the semiannulus, north-east of the storm, in middle latitudes, the tendency of the wind to blow outwards on all sides from the centre may cause the wind in the beginning of the storm to blow so as to appear to whirl from left to right, on the east side of the storm, and from right to left on the west side.

"As the air comes downwards in the semiannulus in front of the storm, it will come under greater pressure, and any clouds which it may contain will probably be dissolved by the heat of greater pressure, and therefore on the passage of the annulus it will probably be fair weather. Also, as the air above always contains more caloric to the pound than the air below, there will be an increase of temperature on the passage of the annulus, partly from the increased pressure, but chiefly by the descent of the air. In very hot climates, this increase of temperature in front of the storm will be very sensibly felt. The increased pressure in the annulus round a volcano, when it suddenly bursts out, will sometimes, under favourable circumstances, be very great, and of course the air will be depressed from a great height; so that some portion of the very air which has gone up in the central parts of the ascending column, and formed cloud by the cold of diminished pressure, will be forced down to the surface of the earth, bringing with it the caloric of elasticity which it received from the condensing vapour; if so, the heat experienced at the time of this descent will be very great.

"These hot blasts of air will alternate with cold blasts; for the air which is forced down from great heights in the annulus will not only be very hot, but very dry, having condensed its vapour in its previous ascent. Now, when this hot dry air flows inwards again towards the volcano, and ascends, it will not form cloud, because of its want of vapour, and therefore the process of cloud-forming will cease, and consequently hail and rain will cease too, until more air from a greater

distance, that has not been deprived of its vapour, flows in and ascends. Then cloud will again begin to form, and the violence and rapidity of the outflowing of the air above will be increased by the evolution of the caloric of elasticity—the barometer will rise rapidly in the annulus, and fall in the central part of the ascending column; and these alternations may continue while the volcano is in activity, more particularly if the violence of the volcano itself should be increased periodically.

"As air cannot move upwards without coming under diminished pressure, and as it must thus expand and grow cooler, and consequently form cloud, any cause which produces an up-moving column of air, whether that cause be natural or artificial, will produce rain, when the complement of the dew-point is small, and the air calm below and above, and the upper part of the atmosphere of its ordinary temperature,

"Volcanoes, therefore, under favourable circumstances, will produce rain; sea-breezes, which blow inwards every day towards the centre of islands, especially if these islands have in them high mountains, which will prevent any upper current of air from bending the up-moving current of air out of the perpendicular, before it rises high enough to form cloud, such as Jamaica, will produce rain every day; great cities where very much fuel is burnt, in countries where the complement of the dew-point is small, such as Manchester and Liverpool, will frequently produce rain; even battles, and accidental fires, if they occur under favourable circumstances, may sometimes be followed by rain. Let all these favourable circumstances be watched for in time of drought (and they can only occur then), and let the experiment be tried; if it should be successful, the result would be highly beneficial to mankind. It might probably prevent the occurrence of those destructive tornadoes which produce such devastation in the United States; for if rain should be produced at regular intervals, of no great duration, the steam power in the air might thus be prevented from rising high enough to produce any storm of destructive character."

Independently of its utility in this manner, Mr. Espy pointed out in what way a knowledge of this theory would be highly useful to the mariner, to enable him to direct his vessel so, when one of these great storms comes near him, as to use as much wind in the borders of the storm as will suit the purposes of navigation; to know in what direction a great storm is raging when it is yet several hundred miles from him; and if the storm should be of such great length, moving side foremost, as to preclude the possibility of avoiding it, to know in what direction to steer his ship, so as to get out of the storm as soon as possible. The sailor also will be able to know when he is out of danger, and by observing storm clouds on their approach to ascertain the direction in which storms move.

On this important subject the author added other remarks and illustrations, which would lose their value by the abridgement rendered necessary by the rules of the Association.

Extract of a letter from Mr. Redfield to Sir J. F. W. Herschel.

New York, July 28, 1840.

Sir,—The interest which you have manifested in the progress of meteorological science encourages me to commit to your care the accompanying plans and memoranda relating to American storms and tornadoes.

The map which illustrates the direction of wind in the great storm of December 15, 1839, at noon, with its accompanying schedule of observations, I beg you to offer to the British Association at the September Meeting in Glasgow—unless you should deem it inappropriate, or consider some other disposition of the same as more desirable—which I submit to your better judgement.

The sketch of the various directions of prostration found in a section of the track of the New Jersey tornado of June 19, 1835, with its schedule of observations, was designed to furnish you with some of the evidences of rotation found in the track of the tornado. Some distinguishing facts, which are thus presented, I deem to have been overlooked by others, or at least misapprehended in their bearing. But, although this single sketch of tornado action was thus mainly intended for your private use, yet, on penning some remarks to accompany it, I was reminded of the claims which Professor Bache had upon me, growing out of my published remarks on the discussion at Newcastle in 1838; and as the subject is not unlikely to engage attention at the ensuing meeting in Glasgow, I have thrown into short compass some of the considerations which appear to me to establish the whirling action.

From these, and various other observations in my possession, I trust to be able successfully to meet (if necessary) any objections which have been, or may be started against the whirlwind theory, as applicable to gales and tornadoes. But for this, it is necessary that the objections should be made in a printed and responsible form, in order that the true state of the case may not be mistaken or evaded.

As regards the map and schedule of observations for the December storm, perhaps I should not have taken the trouble to prepare them, had it not been intimated to the public in reference to my former account of this storm, as it appeared at sunset, that had the observations been given for the middle of the day, the wind arrows at Nantucket, at Cape Cod, and at New Bedford, and with the ship Morrison, would all have pointed in towards a central line.

It has long been my intention to prepare and publish a more full examination of the phænomena of the New Jersey tornado and other destructive whirlwinds, but my avocations and habits are not the most favourable to the execution of this design. I beg you to make such disposition of the paper now sent as you may deem most desirable and proper.

I am, with great respect,

Your most obedient servant,

W. C. REDFIELD.

The documents to which this letter refers were not received in time to be laid before the meeting.

On the Dew-Point. By Dr. Anderson.

The author explained the principles of the formula, which he deduced several years ago from the experiments of Dalton and Gay-Lussac, for determining the various objects connected with the hygrometric state of the air; and showed, by means of tables which he had constructed from it, the facility and despatch with which the absolute

as well as the relative humidity of the atmosphere, together with the dew-point, might be obtained. He concluded his observations on the subject by pointing out the exact coincidence which holds between the dew-point and the minimum nocturnal temperature; and proved that the quantity of moisture in the state of vapour, which exists in the air in every region of the earth, operates as a check upon the diminution of temperature by radiation during the night; for this obvious reason, that the transition of the aqueous vapour to the liquid state evolving its latent caloric, warms the circumambient air, and by giving birth, at the same time, to clouds in the form of vesicular vapour, counteracts the cooling processes to which the nocturnal air is exposed in the absence of the sun. This fact, so important in meteorology, affords an illustration of the reason why the windward sides of continents and large islands are warmer than their leeward sides, in the same parallel of latitude; and why dry and parched tracts of land are always found liable to severe cold during the night. It also furnishes an explanation of the causes which occasion the deflections of the isothermal lines, when taken in connexion with the modifications which these lines receive from geographical position and elevation above the earth's surface,

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On a Method of Prognosticating the probable mean Temperature of the several Winter Months from that of corresponding Months in the preceding Summer. By Graham Hutchinson, *Esq.*

From the slowness with which the increased temperature of summer penetrates the surface of the ground, it occurred to the author, that the last portion absorbed during the summer half of the year, and which descends to the least depth below the surface, should be the first portion given off during the winter half; and in like manner, that the first portion absorbed during the summer half, and which must descend to a greater depth below the surface than any other portion, should be the last to be given off during the winter half; and agreeably to the principle above stated, the months in which an absorption of heat takes place, should have corresponding months of retrocession, or some approximation thereto; and consequently that the mean atmospheric temperature of any month in the summer half of the year, would afford a means of prognosticating the mean temperature of its corresponding month in the winter half, so far at least as that mean atmospheric temperature depended upon the retrocession of heat absorbed during the previous summer half. The corresponding months of temperature assumed by the author, are as follows:—

August has	October following	for its corresponding month of temperature.
July ..	November ..	
June ..	December ..	
May ..	January ..	
April ..	February ..	

If, then, August be warmer than its average, the mean atmospheric

temperature of October following should likewise be warmer than its average: on the contrary, if August be colder than average, October following should likewise be colder than average. The same method applies to the other months.

If there were no other cause for variations in the mean temperature of the winter months in different years, except differences in the amount of solar heat absorbed during the months of corresponding temperature in the previous summer half of the year, the mean temperature of each winter month would always bear a strict relation to that of its corresponding previous summer month; and, consequently, if the one were known, the other could with certainty be predicted. But there are other causes which diversify the mean temperature of the same months in different years; and these being independent of the one under consideration, may either be co-operating with it, or acting in opposition to it. For instance, the proportion of northerly and southerly winds, and the amount of rain that falls during the same winter months of different years, varies greatly. Whether, therefore, among so many other distinct causes of diversity of temperature, the difference in the amount of solar heat absorbed during the summer months does sensibly affect by its retrocession the mean atmospheric temperature of the corresponding months of temperature during the subsequent winter season, so as to afford any probable means of prognostication, can only be determined by reference to statistical tables of the mean temperature of the different months in a succession of years.

From tables then referred to, Mr. Hutchinson said, it appeared that in Scotland deviations in the mean temperature of the summer months have a visible influence in producing like deviations in their corresponding months of temperature in the subsequent winter half of the year. It appeared also, that in the generality of years, the other disturbing causes which diversify the temperature of the same winter months in different years, such as variations in the direction and force of the winds, &c. have less influence, when averaged for a month, than we would be apt, *à priori,* to suppose. And when the same months, for a number of years, are grouped together, and compared as is done in the tables, the disturbing causes, which may occasion a great deviation from the mean temperature in any particular month in one year, seem partially to neutralize each other, and render the influence of unusual warmth or unusual coldness, in any summer month, in producing a similar degree of unusual warmth or coldness in its corresponding winter month, more apparent than could have been anticipated.

The author concludes by some observations as to the most suitable hour of registering temperature for the purpose of testing and applying his speculations (preferring 11 a.m.), and notices as an inference from the simple consideration of the ratio of solar radiation in summer and winter, that the dependence of winter temperature on summer heat, according to the plan of examining it already exemplified, should be greater and more obvious the higher the latitude of the place of observation.

On Excessive Falls of Rain. By Professor FORBES.

"It appears, from the report of the Birmingham Meeting of the British Association, as given in the *Athenæum* (No. 618), that doubt has been thrown on the statement of the remarkable fall of rain cited in my former report. I was not present at either of the discussions alluded to; I therefore take this opportunity of stating the authority upon which these very surprising falls of rain were admitted into my report,—authority so ample, that, as an historian of science, I could not have omitted them, improbable as they do most certainly appear. The fall of thirty inches of rain within twenty-four hours, took place at Genoa [not Geneva, as printed in the report] on the 25th of October, 1822. An assertion to this effect having appeared in a Genoese newspaper, the editors of the *Bibliothèque Universelle* wrote immediately to make the necessary inquiries as to an observation so unprecedented. The reply which they obtained from M. Pagano, 'observateur exact*,' is given at length in their journal, and is not, I think, the less satisfactory, because this result was obtained by the most inartificial of rain-gauges. 'Deux sceaux de bois presque cylindriques, dont l'un de vingt-quatre et l'autre de vingt-six pouces de hauteur, qui m'avoient servi pour quelques expériences sur la vendange, étoient restés vides dans mon jardin. La pluie de Vendredi 25 Octobre n'avoient pas encore cessé de tomber que déjà ils en étoient remplis.' He then proceeds to state on what grounds he infers that four inches more of rain fell after the larger vessel had been filled, making a total of thirty inches French (thirty-two English); and adds a statement of several facts, to show that the effects of the deluge in the neighbourhood bore a proportion to the magnitude of the cause. M. Arago, quoting the result, adds: 'Ce résultat inouï inspira des doutes à tous les météorologistes, on soupçonnait une erreur d'impression; mais M. Pagano, observateur exact, a écrit aux rédacteurs de la *Bibliothèque Universelle* une lettre qui *met le fait hors de toute contestation* †.' Fortunately, however, this *local deluge* (for it appears, by the letter of M. Pagano, to have extended but a very short distance,) is nearly rivalled by a similar *fact* recorded in the south of France by an experienced observer, who seems to have been in the practice of measuring the fall of rain for twenty-three years at least, M. Tardy de la Brossy, of Joyeuse, Dép. de l'Ardêche. M. Arago, who records the observation, and gives it the weight of his authority, does so in these words: 'Le 9 Octobre 1827, dans l'intervalle de vingt-deux heures, il est tombé, dans la même ville de Joyeuse 29 pouces 3 lignes d'eau (vingt-neuf pouces trois lignes). J'écris le résultat en toutes lettres, afin qu'on ne croie pas à une faute d'impression ‡.' When I add, that these two results, surprising, and perhaps unexampled as they are in the history of science, have, on

* Vol. xxii. partie *Physique*, p. 67.
† *Ann. de Chim. et de Phys.* xxvii. 407.
‡ *Ann. de Chim. et de Phys.* xxxvi. 414.

account of the testimony by which they are established, been received not only in France and Switzerland, but in Germany and England, I conceive that they are undoubtedly entitled to stand part of the history of meteorology. I proceed to add a notice of a few other remarkable falls of rain, though there is nothing on record comparable to the two preceding ones. Flaugergues, the eminent meteorologist of Viviers, obtained, on the 6th of September, 1801, 13 inches 2·3 lines ($14\frac{1}{2}$ English inches) of rain in eighteen hours. On the 20th of May, 1827, there fell at Geneva 6 inches of rain in *three hours*. At Perth, on the 3rd of August, 1829, there fell 4-5ths of an inch in half an hour. On the 22nd of November, 1826, I observed at Naples a fall of 9-10ths of an inch of rain and hail in thirty-seven minutes. Were the equatorial records of the fall of rain as minute in respect of distribution as of total amount, we should doubtless have records of enormous falls within twenty-four hours; none so recorded, that I am aware of, approaches the results at Genoa and Joyeuse. From the total quantities measured, it is evident that the result for particular days must be enormous. Don Antonio Lago observed at San Luis, Maranham ($\frac{1}{2}^{\circ}$ S. latitude), a fall of 23 feet 4 inches 9·7 lines in a year. Roussin states (his account is confirmed) that at Cayenne (5° N. lat.), in February, 1820, there fell, in ten hours, 1·25 inch of rain; and between the 1st and 24th of February, *twelve* feet 7 inches. From observations in the Ghauts, it appears that, in the eastern hemisphere, in lat. 18° N., 302·21 inches of rain have been measured; a quantity exceeding that stated on the authority of Roussin, and which was once considered almost incredible; and of this quantity (25·2 English feet), nearly 10 feet fell in the month of July alone."

Col. Sykes communicated the contents of a letter from India, from Capt. Aston, one of the diplomatic agents of the government of Bombay, in Kattywar, on the subject of a recent singular shower of grain. He stated that full sixty or seventy years ago, a fall of fish, during a storm in the Madras Presidency, had occurred. The fact is recorded by Major Harriot, in his "Struggles through Life," as having taken place while the troops were on the line of march, and some of the fish falling upon the hats of the European troops, they were collected and made into a curry for the general. This fact for probably fifty years was looked upon as a traveller's tale, but within the last ten years so many other instances have been witnessed and publicly attested, that the singular anomaly is no longer doubted. The matter to which he had to call the attention of the Section was not to a fall of fish, but to an equally remarkable circumstance, a shower of grain. This took place on the 24th of March, 1840, at Rajket, in Kattywar, during one of those thunder storms, to which that month is subject; and it was found that the grain had not only fallen upon the town, but upon a considerable extent of country and round the town. Captain Aston collected a quantity of the seed and transmitted it to Col. Sykes. The natives

flocked to Capt. Aston, to ask for his opinion of this phænomenon; for not only did the heavens raining grain upon them excite terror, but the omen was aggravated by the fact that the seed was not one of the cultivated grains of the country, but was entirely unknown to them. The genus and species was not immediately recognizable by some botanists, to whom it was shown, but it was thought to be either a spartium or a vicia. A similar force to that which elevates fish into the air, no doubt operated on this occasion; and this new fact corroborates the phænomena, the effects of which had been previously witnessed.

New Experimental Researches on Rain. By JOHN PHILLIPS, *F.R.S.*

The author proposed, by a new train of researches on the quantities of rain received on horizontal surfaces at *different heights* above the ground, by a contemporaneous series of experiments on the *direction* and angle of *inclination* of the descending lines of rain drops, and by contemporaneous registration of wind, temperature and moisture, to furnish additional data of importance in the theory of rain. Referring to the results obtained in his former discussion of three years' observations on the quantities of rain on York Minster (212 ft. above ground), the Yorkshire Museum (42 ft.), and on the ground, made by Professor Phillips and Mr. William Gray, the author noticed the statements of Prof. Bache, Dr. Daubeny, and others, as to the inequality of the receipt of rain about the angles of a building and at small heights above it, in consequence of local aerial deflexions; and though in these respects the experimental results obtained in the three years' York series appeared liable to small objection, many reasons of importance decided that in this new course of experiments, destined to last many years and to include a variety of contemporaneous records, the rain gauges should be placed in an open ground. It was further determined to place them at heights above the ground, corresponding to the depths below the surface to which the thermometers of Arago, Quetelet and Forbes, are sunk; i. e. to 0, 3, 6, 12, and 24 French feet. At present there are placed in the author's garden-ground four gauges at heights of 0, 3, 6, 12 French feet. The method of observation is of a peculiarly easy description, so that in the midst of rain the momentary rapidity of the fall of rain can be perfectly ascertained in all the gauges. For example, in a *very heavy* shower, the *maximum rapidity* of rain accumulation, was 0·010 inch in two minutes of time = 0·300 inch in an hour. The gauges are, in common language, *of the same size*; but the author, not trusting to this supposed equality, makes the four gauges pass through a circle of positions, so that at the end of a year about 12 changes of position will have occurred, and the error of size in any one or more of the gauges be equally distributed over the various positions, and the registration be finally correct, without any applied calculation. The results, from June 1 to September 3 inclusive, in which period the changes of the gauges have not been sufficient to equalize their errors, are—

12 feet above ground	8206
6 feet above ground	8249
3 feet above ground	8314
0 feet above ground	8408

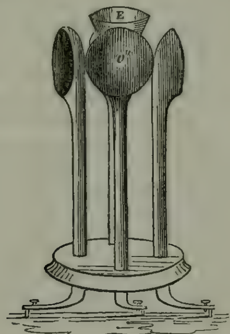
During this period it has sometimes happened that more rain fell in the upper gauges, a circumstance apparently dependent on the dryness of the air, which has been very remarkable in the early part of the period in question.

	1.	2.	3.	4.
June 30	1575	1547	1509	1508
July 12	2018	2030	2046	2022
Aug. 14	2347	2315	2300	2260
Sept. 3	2468	2422	2394	2416
	8408	8314	8249	8206

maximum rate ·0100 in $2' =$ ·300 in one hour.

In the second part of his communication the author describes a new construction of rain gauge for the purpose of determining the direction in which rain comes, and the angle of inclination at which it descends.

For this purpose a compound gauge is constructed, having five equal receiving funnels and tubes; one with a vertical tube and horizontal aperture, the other four with tubes recurved so as to present the openings of the funnels in four vertical planes directed to four quarters of the horizon (see diagram),



where h is the horizontal funnel, v', v'', v''', three of the four vertical openings, and c' c'' c''', three corresponding cocks for letting off the water into a graduated tube.

The rain which falls in the funnels h, v' v'' v''' v'''' being carefully measured *after each shower*, the observer is able immediately to determine the direction and inclination of the rain in each of the following cases:—

1. If the rain has fallen in a direction exactly coinciding with any one of the vertical funnels, that and the horizontal funnel alone receive any

rain. The direction thus known by observation, the angle of inclination of the descending rain from the vertical is easily calculated.

2. If the rain has fallen (in quantities q and q') in two of the vertical gauges as well as in h (in quantity H), then the direction of the rain, intermediate to the positions of the two receiving vertical gauges, may be easily calculated (by considering q and q' as sine and cosine; the ratio between them being = cotangent of the angle by which the rain direction deviates from that of the gauge which receives most rain). This known, the quantity (Q) which *would have been received*, in a vertical funnel directly opposed to the rain, is also calculable, being $= \sqrt{q^2 + q'^2}$; and, finally, the angle of inclination from the vertical, at which the rain descends, is calculable, its cotangent being $= \frac{H}{Q}$.

Observations with this instrument have been made satisfactorily for some months, and the author has found the angle of inclination of descending rain to vary from 0 to 6°, 13°, 17°, and in one case to 35°, without perceiving that these very unequal inclinations had any sensible effect on the relation of the quantities of rain received in the gauges which are placed at different elevations.

On the Formation of Rain. By G. A. Rowell.

The author states his hypothesis, that vapour on rising carries with it its proportion of electricity according to its *expanded surface*, and on being condensed, becomes, if insulated, surcharged with electricity; this buoys up the vapour by its lightness, and prevents the formation of rain by its repulsive power, and, on its escape, the particles of vapour attract each other and form rain. He then explains the phænomenon of rain, as follows:—That hills and mountains being more subject to rain than plains, is owing to their attracting the electricity from the clouds or invisible vapour; that the rain accompanying fire on the eruption of volcanos is from the dense columns of vapour and smoke conducting the electricity from the clouds to the earth; that each particle of vapour in a cloud is of the same density, therefore the pressure of gravitation in the vapour may overcome the repulsion of electricity and form rain where the clouds are piled to a great height, and that any violent commotion in such a cloud would cause such heavy rains as follow flashes of lightning; that the *successive flashes of lightning from the same cloud* may be from vapour becoming more and more condensed, thus causing successive accumulations of electricity on the surface of the vapour, or from the decrease of extent of surface in the cloud by the particles of vapour coalescing and forming drops of rain, thus causing similar accumulations; that the change in weight of the atmosphere previous to and during rain, is caused by the electricity passing from the cloud or invisible vapour to the earth, displacing the heavier air, and thus causing

the atmosphere to be lighter; that the greater quantity of rain falling on the earth than at any elevation in the same locality, is occasioned by each falling drop of rain attracting to itself every particle of invisible vapour which may be floating within the sphere of its electrical attraction, and thus increasing its bulk.

The paper concludes with proposing the experiment of raising electrical conductors to the regions of the clouds by means of balloons; which, in the author's opinion, would withdraw the electricity, and cause clouds and rain to be formed.

On the Cause of the Aurora, &c. By G A. Rowell.

The phænomenon of the aurora is explained thus:—The vapour rising at the equator, being greatly expanded, ascends to a great height with a great accumulation of electricity; is thence carried by the currents of air towards the poles, where the electricity again escapes to the earth and rushes along its surface, and the vapour in the lower parts of the atmosphere towards the equator is again carried off, thus causing currents of electricity; this circulation continues freely while the air at the poles is damp; but during the severe frosts of winter in the frigid regions, the air, near the earth's surface, is nearly or quite dry, and the aurora is exhibited by the electricity passing through this non-conducting medium.

By these currents, and the supposition that magnetism is owing to the attraction which the magnet has for electricity, which from some peculiarity can pass through it in one direction only, and that there be two sorts of electricity, one predominating in each hemisphere, the various phænomena of magnetism are explained thus:—The direction of the needle is owing to its being attracted in the direction from which the streams passing through it are derived, the streams in this hemisphere converging to the north pole, and diverging or escaping from the south pole to gain their equilibrium; that the dip is caused by the currents derived from the earth being stronger than those from the air and vapour above the needle; that the variation is owing to the greater quantity of electricity received by the earth at the magnetic poles, diverging east and west to gain its equilibrium in passing towards the equator; that the probable cause of the great quantity being received at these parts of the earth, is from the height of land conducting the electricity to the earth, or because the temperature is constantly lowest at these points of the earth, thus causing a draught of air, vapour, and electricity, from the warmer parts of the earth through the upper parts of the atmosphere; and that the daily variation is occasioned by the greater or lesser formation of vapour, according to the direct action of the sun on different parts of the earth.

The repulsion of similar and attraction of opposite poles of the magnet is thus explained:—The needle is kept in its magnetic meridian by the converging streams to the north pole: now if the north pole of

a magnet be brought near the north pole of the needle, the streams on that side are intercepted by the magnet, while the streams on the opposite side attract the needle with the *appearance* of its being repelled by the magnet; or, if the south poles be brought near, they *appear* to repel, by the diverging streams being attracted in opposite directions to gain their equilibrium; but the opposite poles attract each other by the streams from the south pole of the one being attracted by the north pole of the other magnet.

The probability that magnetism is owing to the passing of some fluid through the magnet, is shown by the fracture of the magnet or by magnetizing a ring, which shows no signs of magnetism until broken, and which again disappears on the broken parts being brought into contact, which is explained by supposing the fluid to circulate within the ring, and therefore no magnetism can be exhibited till the line of continuity be broken.

The author supports his opinion by general reference to the observations on the aurora, &c., in the Appendix to Captain Franklin's Journey to the Polar Seas, and concludes with proposing the experiments of raising electrical conductors to the height of the clouds in the *frigid regions during the frosts in winter*, which in his opinion would cause the aurora to be exhibited, and lead to important discoveries in the science of magnetism.

Observations on the Tides in the Harbour of Glasgow, and the Velocity of the Tidal Wave in the Estuary of the River Clyde, between Glasgow and Port Glasgow. By William Bald, *F.R.S.E., M.R.I.A., &c.*

The first series of observations made on the tides was commenced the 26th of April, 1839, and extended to the 1st of October, 1839; it has been tabulated, and contains 158 observations of the rise and fall of the tides. It is necessary to observe that during the first portion of the time these tide observations were only made during the day, and did not extend to the night tides. These 158 observations assign a mean rise and fall of tide in the harbour of Glasgow of 6 feet 7·20 inches.

The number of tide observations made from the 1st of October, 1839, to the 27th of August, amounts to more than 1200. These are tabulated and divided into months, but such of the tides as have been much disturbed by floods have been rejected.

The mean rise and fall of these 1213 tides, assigns an average of 6 feet 8·98 inches.

Mr. Bald presented tables in which were contained the principal results arrived at, by comparing the periods of new moons, first quarter, full moon, and last quarter, and diagrams representing the observations in a continuous line. He has also drawn out eight sections, showing the perpendicular rise and fall of the tide for every fifteen minutes in the harbour of Glasgow, at Clyde Bank, Bowling Bay, and Port Glasgow.

He has also measured the velocity of the ebbing and flowing of the tidal current in various parts of the River Clyde, from Glasgow Harbour to Port Glasgow.

It appears from these observations that the tidal wave runs from Port Glasgow to Bowling at a rate or velocity of 14·56 miles per hour; from Bowling Bay to Clyde Bank at a rate of only 6·82 miles per hour; but from Clyde Bank to Glasgow Harbour at a rate of 10·85 miles per hour. The diminished velocity between Bowling Bay and Clyde Bank arises from the channel of the river being more crooked in that part than in any other portion of the River Clyde, thereby showing the great necessity of straightening and improving it.

On the Theory of Waves. By the Rev. Professor KELLAND.

The objects of the present communication are twofold: first, to present the subject of the Theory of Waves in its present form, and then to point out the difficulty which appears likely to impede its progress.
1. The object of the theory is to account, on mechanical considerations, for such phænomena as are presented by the destruction of equilibrium of a fluid, and to obtain and to interpret mathematical expressions which give the velocity, form, impulses, and other circumstances of the motion. Our problem, then, divides itself into two parts; 1, the determination of the conditions which are presented by the nature of the fluid on the hypothesis that it *is* in motion; 2, the investigation of the effects which will *immediately* follow the disturbance of equilibrium. The first of these problems alone presents no considerable difficulty; at least the difficulties are not such as to have deterred many writers from engaging to solve it. Laplace led the way, and was followed by Lagrange, Poisson, and others. As far as the author knows, however, all the writers on the subject confine themselves to two cases, viz. when the depth of the fluid is either very great or very small, in comparison with the length of a wave. Aided by their discoveries, he attempted, in a memoir read before the Royal Society of Edinburgh last year, and published in vol. xiv. of their Transactions, to supply the deficiency, and to obtain the equations of motion of a regular set of waves, without imposing any restriction on the conditions. This was effected by assuming that a reciprocating function can always be expanded in a series of sines and cosines of multiples of the space through which the whole series of values extends. This assumption, which is frequently made by Fourier and others, leads directly to the complete solution of the problem. The author has since applied himself to the completion of this part of the subject by solving the problem in cases in which the depth is variable, which had only been partially executed before. In the first place, he considers that case in which the depth is variable in the direction of the breadth, but uniform in that of the length. In his former memoir he contented himself with an approximate solution, founded on a particular hypothesis. The results, approximate as they confessedly were,

agreed remarkably well with the experiments of Mr. Russell. His present more complete formulæ are such, that, for all cases in which the form of the canal is expressed by an equation between a power of y and a power of x, they lead precisely to the results which he previously obtained. One remarkable circumstance he pointed out, which is this; that if the form of the wave can be expressed by a *single* function, the velocity is the same in the middle of the canal as at the edges. Perhaps this apparently anomalous conclusion may arise from the circumstance that we assume the same form of wave to pertain to all parts of the canal. Another result of his analysis is, that the height of the wave increases very rapidly as we proceed towards the edge of the vessel, to the detriment, as it would appear, of the height of the centre.

He next endeavours to obtain the motion of a wave in a canal, the depth of which is continually but slowly varying in the direction of the length. He here employs the method of the variation of parameters, and obtains the following results:—

1. That the length of the wave is in direct proportion to the depth.
2. That the velocity of transmission at *any* point varies as the square root of the depth.
3. The elevation of the crest of the wave varies reciprocally as the total depth of the fluid.

Lastly, he discusses the problem which Messrs. Poisson and Cauchy had solved for the particular case, where the depth is very small or very great. It is well known that these philosophers undertook the solution of this problem in competition for the prize offered by the French Institute. As neither of these memoirs is printed exactly as it was originally delivered in, it would be hard for us to draw any conclusions from the judgement pronounced by the judges. We know that M. Fourier found fault with Poisson's solution on the ground that the function was limited in its value. The prize was accordingly adjudged to Cauchy. The plan which Poisson adopts, it is very easy to understand; viz. he finds a solution of the general equation of wave motion, and arranges it so as to make it coincide with a formula given by Fourier, which expresses the relation between a function and a particular value of the function.

M. Cauchy, on the other hand, demonstrates a formula slightly differing from Fourier's, and by means of it, he too expresses the general function in terms of the particular. Now it happens that M. Cauchy's formula does not render necessary any limitation as to the depth of the fluid. Indeed, M. Cauchy himself discovered this, and published it in a note, but he never, to the author's knowledge, made any further use of it. Some of the results obtained by both philosophers, are found by the author to be true without all the limitations which they have imposed. But there is one point of the utmost importance, viz. the determination of the length of the wave, for which their results are not satisfactory. Those who are acquainted with the analysis employed by the philosophers to whom he has referred, will remember that the integrals to be obtained may, by arranging in different forms, be made

to express different motions. Thus the *ondes dentelées*, and the waves of constant transmission, are alike expressed, and their *length* is determined in a function of the disturbance, &c. Now it appears to the author, that the same expansion which leads to the waves of constant transmission, ought, when the circumstances of the motion are assumed to be such as to admit of it, to lead also to the wave of solitary translation. If it do not, then it would appear that the theorems of Fourier and Cauchy cannot give in terms of x a discontinuous function of the nature required, or such that its differentials with respect to x and y shall vanish at the same time. If, on the other hand, the theorems do suffice to express the requisite function, then shall we expect to find not the velocity only, but the complete *form* of the wave, which results from a given disturbance. We shall, in fact, be furnished with the length of the wave. It ought to be stated, that the author has sought in vain to deduce it from the equation which gives the velocity of transmission, and with as little success from the *value* of the discontinuous function which he used in his first memoir; but with the general formula itself, although he has not positively discovered the impossibility of discovering the thing sought for, he has yet found considerable difficulties. The principal of these is the multitude of series which must be accurately summed before the equations can be formed. He was in consequence led to point out such difficulties to the Association, with the hope that some member might take up the subject, and, by removing them, render the subject susceptible of application to the theory of the tides*.

On the Agency of Sound. By Mr. SHAND.

The author commenced his paper by remarks on the neglect manifested toward preserving or assisting our hearing; and having laid down, in a series of propositions, his views regarding the origin and conduction of sound, observes, that it is difficult to reason on the operations of nature and the motions and influence of matter not perceptible to the eye. In the present case, however, we are enabled to judge partly by our ocular faculty and in part from our sense of hearing. That the vibratory and undulatory or oscillatory motions are not only prevalent in the musical string, but in all matter in a state of agitation, is indicated by the following facts :—1st. In a musical string of a given diameter and tension, when set in motion, the extent of the undulations is in the ratio of the length of the string—each undulation gives out a distinct sound, conformable in duration to the extent of the undulation. 2nd. In the walls and ceiling of an apartment these principles of action are also equally apparent; wherever there is an extended surface in any one place, the undulations are also extended, and these produce distinct sounds in the ratio of their extent. If the

* At the request of the General Committee, Professor Kelland has undertaken to draw up a report on this subject, to be presented to the Association.

reflections of the human voice, by this means, be prolonged, the reflection of one letter falls upon the original sound of another letter, and occasions as much derangement as if one syllable or word were intermixed with another syllable or word; as one letter differs in sound from another letter as much as do syllables or words. This is one great and leading error in the construction of places for public speaking; and it is alone sufficient to show how fallacious the idea is of relying on the mere form of an apartment, without attending to and regulating this action, in not only the walls and ceiling, but in every reflecting body in an apartment, especially in glass, which is the most sonorous material. 3rd. The same rules of action are exhibited in water. In the ocean, the reach of sound is regulated according to the expanse of water: where there is an indent in the land, the wave is extended, and the sound it produces is prolonged. Were this action regulated by the current of air only, the waves would pass in one uniform direction; but this is not the case. 4th. These principles of action are, however, more perfectly defined in the atmosphere, through which sounds are transmitted with least change, and are preserved separate and apart from each other.

Having in view mainly the economy of speech in apartments, Mr. Shand stated the following facts and reasoning: An individual who is so deaf that he is insensible to upwards of a thousand people singing in a church, on applying one end of a forked piece of wood to his teeth, and the other end to the ledge of the division of the seat before him, is enabled by this to hear and join in the tune. Now it is not merely the partial agency of this wood that is to be considered, as, by the spread of the atmospheric vibrations, the voice sets in motion every atom of every solid in the church, and it is distributed throughout these with more rapidity and intensity than by the air, which is incapable of communicating the same measure of vibratory influence at any one given point; and it evinces that, being the more rapid and profuse conductor, it is the wood that is most rapidly set in motion, and communicates action and sound to the air in a room. If these observations be correct, nothing can be more erroneous than to suppose that speech can be regulated within the walls of an apartment without regulating the action of the solids, which predominantly govern it in this case. If sound predominates more in the fibre of the wood of the stethoscope than in the aërial passage in it, must not the same rule apply in a church, where the seats and lathing are almost invariably of pine?

Mr. Shand proceeded to remark on the peculiarities with regard to sound which he had observed in certain buildings. In the Albion Church, in Glasgow, he heard the speaker with perfect distinctness when he spoke in his natural tone, as his voice was mostly reflected by the walls, which are of solid masonry; but when his voice was raised so as to act with more force on the ceiling, the longer excursions and undulations of the then hollow ceiling produced prolonged reflections, which drowned speech. In St. Andrew's Church very different effects are produced in the galleries and lower part of it. In the galleries the ceilings are

low and curved, and the voice, acting within the curvatures, produces prolonged and concentrated reflections (as in all such cases) inimical to speech; the windows are much exposed to the voice, and the divisions of the seats rise too much above each other, all which occasion lengthened reverberations, to the prejudice of speech. The asperities presented by the ornaments on the walls, and the capitals of two ranges of Corinthian pillars, occasion harsh reflections, which are unpleasant. All these defects are, however, lost in a great measure in the lower part of the building, where little inconvenience is experienced. In Dr. Lee's church, in St. Giles's, Edinburgh, in which the General Assembly met, but were obliged to abandon it as their place of meeting, the arrangements are such that the preacher is very indistinctly heard at the distance of twenty feet, and there are two galleries at the extremities of the church which are locked up as useless. Similar causes produce similar effects in St. Luke's Church in Liverpool. Here there is a locomotive pulpit, for the purpose of rolling the preacher from place to place; but there is even a gross evil in this vehicle, which accompanies it and the speaker to whatever point he may be conveyed. The canopy over his head is a deep hollow body, formed of thin deal; it is literally a drum, as may be understood by striking it, and produces deep hollow sounds, operating in a transeverse direction, and most prejudicially on the voice of a speaker. The author notices several other cases, and states that it is not by creating additional or increasing reflected sounds, but by bringing the action of the reflecting surrounding solids to move in time with the mechanism by which speech is produced, and by this means, reflected sounds to accord with every distinct letter that the speaker pronounces; it is by shortening the action, and limiting the time of each distinct reflection from the glass, thin deal boards, &c., to the time in which each letter is formed by the speaker. This, in fact, however simple it may seem, must be effected, otherwise no form in the walls of an apartment for public speaking can accomplish what is necessary for the economy of speech.

On a Method of approximating to the Value of the Roots of Numerical Equations. By Mr. GRAHAM.

On the Expressibility of the Roots of Algebraic Equations, By Mr. PEEBLES.

Since the function of the coefficients which expresses the general root of an equation must be such as to represent all the roots, the author seeks to discover that particular function of its quantities. After proving that various combinations will not suffice, he shows that certain others will do so in certain cases.

Notice of Mr. Fowler's *new Calculating Machine. Communicated by Professor* Airy.

The origin of this machine was to facilitate calculations of the proportions in which the several divisions of a poor-law district in Devonshire were to be assessed. The chief peculiarity of the machine is, that instead of our common decimal notation of numbers, a ternary notation is used; the digits becoming not tenfold but threefold more valuable as they were placed to the left; thus, 1 and 2 expressed one and two as in common, but 1 0 expressed (not ten, but) three, 1 1, four, 1 2, five; but again 2 can be expressed by 3, with 1 taken from it. Now, let $\bar{1}$, written thus, with a small bar above it, mean that it is subtractive; then $1\ 2$ and $2\ \bar{1}$ are the same in effect, both meaning five; and, for a similar reason, replacing 2 by its equivalent $1\ \bar{1}$, we have five written in three several ways: $1\ 2$, or $2\ \bar{1}$, or $1\ \bar{1}\ \bar{1}$; the last is the form used. It is obvious, that by an assemblage of unit digits thus positively or negatively written, any number may be expressed. Thus the number which decimally expressed is 70, becomes in the ternary system 2121: and 2 being equal to $1\ \bar{1}$, this may be made $10\overline{111}$. In the machine, levers were contrived to bring forward the digits 1 or $\bar{1}$, as they were required in the process of calculation. A full description of the machine, drawn up by Professor De Morgan, was presented by the author.

On a Mode of solving Cubic Equations. By Mr. Walsh.

New Logarithmic Calculations and Views. By Wm. Hoyle.

On a new Construction of Barometer. By P. McFarlane.

The author proposed to substitute the weighing of a mercurial column, for the measure of its length, and by contrivances in accordance with this principle, to reduce or extinguish the disproportion which exists between the common barometrical linear measures, and the variations of physical condition on which the change of these measures depends.

On the four daily Fluctuations of the Barometer. By Mr. Espy.

When the sun rises the air begins to expand by heat; this expansion of the air, especially of that near the surface of the earth, lifts the strata of air above, which will produce a reaction, causing the barometer to rise; and the greatest rise of the barometer will take place when the increase of heat in the lower parts of the atmosphere is the most rapid, probably about 9 or 10 a.m. The barometer from that time will

begin to fall, and at the moment when the air is parting with its heat as fast as it receives it, the barometer will indicate the exact weight of the atmosphere. The barometer, however, will continue to descend on account of the diminishing tension of the air and consequent sinking upon itself as the evening advances; and its greatest depression will be at the moment of the most rapid diminution of temperature, which will be about 4 or 5 o'clock.

At this moment the barometer will indicate a less pressure than the true weight of the atmosphere. The whole upper parts of the atmosphere have now acquired a momentum downwards, which will cause the barometer to rise above the mean as the motion diminishes, which must take place some time in the night. This rise will be small, however, compared with that at 9 or 10 a.m. As the barometer now stands above the mean, it must necessarily descend to the mean at the moment when it is neither increasing nor diminishing in temperature, which will be a little before sunrise. If this is the true explanation of the four fluctuations of the barometer in a day, it will follow that the morning-rise ought to be greater at considerable elevations, provided they are not too great, because some of the air will be lifted above the place of observation; and such was found to be the case by Col. Sykes in India.

On the Meteorology of Perth. By Dr. Anderson.

Perth is elevated about 30 feet above the mean level of the ocean, and situate in lat. 56° 23′ 40″ N., long. 3° 26′ 20″ W. Dr. Anderson stated that the magnetic variation, which seemed to have reached its maximum in 1815, was 26° 54′ W. in Nov. 1836; and that the magnetic dip was 72° 10′ in May 1838. The mean barometrical pressure, deduced from a period of six years of consecutive observations, continued from 1829 to 1835, was 29·802, the time of observation being nine o'clock in the morning. By a comparison of the means of each month, for the several years, with the mean of the entire period, it appeared that the means in defect greatly exceeded those in excess; from which he concluded, that the disturbing causes which produce a diminution of atmospherical pressure are more sudden, as well as more powerful in their operation, than such as give birth to an opposite condition,—a result which implies that the causes contributing to a low state of the barometer are of limited extent and partial influence,—and may be explained by referring them partly to the diminution of aerial elasticity occasioned by a rapid condensation of aqueous vapour, and partly to the combustion, by electricity, of large portions of carburetted hydrogen in the upper regions of the atmosphere over the place of observation. Hence he inferred that an arithmetical mean between two observations, the one expressing the highest and the other the lowest height of the mercury, will rarely give the true average height for the mean interval of time between the observations.

The mean annual range of the barometer at Perth, derived from a period of nine consecutive years, is 2·189 inches; but the extreme

range for the same time, or the difference between the highest and lowest altitude of the barometer, was found to be 2·821 inches. The fluctuations or deviations from the mean state are greatest in December and smallest in August. The mean temperature of Perth, derived from the maxima and minima of each day, according to observations continued from the beginning of 1829 to the end of 1834 inclusive, is 48°·14. The mean obtained from the annual means, by observations taken at nine o'clock in the morning, and half-past eight in the evening, is 47°·9; and the mean of the annual extremes, derived from the greatest heat and greatest cold, for each year, is 48°·25. Lastly, the mean of the highest and lowest temperature for the entire period of years is 47°·5. By a comparison of the mean temperature of the several months, it appears, that in different years the month of July possesses the greatest uniformity of temperature, and the month of January the least. The temperature of March, April and May, especially that belonging to the last of these months, has a considerable range in different seasons, on account of the variable winds in spring; and the temperature of August and September seems to be still more fluctuating, a circumstance that occasions the late and early harvests, which happen in different years. The lowest temperature, within the period to which the above observations refer, occurred on the 26th of December, 1830, when the instrument stood at 16°, and the greatest heat took place on the 28th of July of the same year, when the thermometer was at 79°. The greatest annual range for that year was therefore 63°; but the mean annual range for the entire period was only 57°·5. The most abrupt change of temperature occurs between the middle of October and the middle of November, and to this must probably be ascribed the increase of pulmonary complaints, which takes place at that gloomy and disagreeable season.

The mean hygrometric state of the air at Perth, is when the atmosphere is charged with about four-fifths of the entire quantity of moisture it is capable of holding in the state of vapour at the mean temperature. The dew-point, which corresponds almost exactly with the minimum temperature, in the case of the different months, is depressed about 6° or 7° below the mean temperature in winter, and about 8° or 9° below it in summer. The month of April possesses the smallest relative humidity, and the month of November the greatest; the former month being, in the ordinary acceptation of the term, the driest, and the latter the dampest month of the year. The mean quantity of rain which falls at Perth, derived from a period of six consecutive years, viz. from the beginning of 1829 to the close of 1834, is 30·89 inches. The greatest anomalies, with respect to the quantity of rain which falls in different seasons, happen in July, in which month the difference between the greatest and least quantity is 4·65 inches; and the smallest occur in November, when the difference is only ·81 inch. The maximum quantity of rain for a period of sixteen years is 31·01 in., and the minimum quantity 15·59 in. The annual number of fine days, deduced from a period of six consecutive years, is 253; and the number of days on which there was either rain or snow, 112; the former being more than double of the latter.

CHEMISTRY.

On the most important Chemical Manufactures carried on in Glasgow and the Neighbourhood. By Professor THOMAS THOMSON, *of Glasgow, F.R.S.*

"Glasgow being the seat of a great many interesting and important chemical manufactures, it occurred to me (said Professor Thomson) that it might be of advantage to those members of the Chemical Section, who have come from a distance, to give a short catalogue of the most important of these manufactures, that they might know what the information is which they may expect, and where they are to look for it."

1. *Iron.*—The smelting of iron has been practised in the neighbourhood of Glasgow for more than fifty years. When the late Mr. Dunlop, of the Clyde Iron Works, first became proprietor of those works, perhaps the only one then in the neighbourhood, the produce was only fourteen tons a-week, or 728 tons a-year. At present the quantity of iron smelted in Glasgow and the neighbourhood cannot be much less than 200,000 tons, which approaches to a fifth part of the whole iron smelted in Great Britain. The ore from which the iron is smelted is the carbonate of iron, or clay iron-stone, as it is usually called by mineralogists. This ore is very abundant all round Glasgow, and especially in the neighbourhood of Airdrie, where the principal works are now situated. Fortunately for the smelters, the iron-stone and coal-beds are associated together, the iron-stone either occurring in nodules or beds along with the coal. The rapid increase of iron smelting has been the consequence of a discovery of Mr. Nielson, manager of the gas-works. This is now universally known under the name of the hot blast. The air is heated to more than 607° before it enters the furnace, by passing through a range of heated pipes. Under this treatment, it is found that the coals may be used without previous coking; and that instead of seven tons of coal for every ton of cast iron, three tons, or even two and a half tons will suffice. There is also a diminution in the quantity of limestone necessary, and the produce of iron per week from the same furnace is considerably increased. It is said, that neither in Staffordshire nor in Wales is the hot blast attended with the same saving of fuel. Till of late years, no bar iron was made in Scotland, the smelters confining themselves to cast iron. About three years ago, Mr. Dixon commenced the manufacture of bar iron near St. Rollox, but, after some time, he abandoned the manufactory. It is now conducted on a great scale, by Mr. Wilson, at Dundyvon, and by Mr. Dixon, at Glasgow, and perhaps by other iron-masters. The heat raised in the puddling furnace is much greater than it was in Staffordshire, when Dr. Thomson witnessed the process there about twenty-five years ago. There is an interesting manufactory of steel at Holytown, not far from Airdrie, where the smelting and casting of steel may be seen: the heat necessary for this process is greater than for any

other. It is curious, that the clay in the neighbourhood answers perfectly for making crucibles for cast steel; but it does not answer so well as Stourbridge clay for making glasshouse pots. On analysing the two clays, it was found that the Garnkirk contained much more alumina and less silica than the Stourbridge; showing that glass in fusion acts more powerfully on alumina than on silica.

2. Another manufacture of importance, and which is indebted to Glasgow for the state of perfection which it has reached, is that of *sulphuric acid.* It was begun by Dr. Roebuck, at Preston Pans, about the year 1763, but it is not more than twenty years since his manufactory was abandoned. The sulphuric acid works at St. Rollox, on the banks of the Monkland canal, were begun about forty-five years ago. They were at first upon a very small scale, though they now probably are the largest of the kind in Europe. Dr. Roebuck's method was to mix together sulphur and saltpetre, and after setting the mixture on fire, to introduce it into a leaden vessel or chamber, at the bottom of which there was a quantity of water. This method was not œconomical. A portion of the sulphur would unite with the potash of the saltpetre, and form with it a sulphuret, and probably a portion of the sulphuric acid formed would also unite to the potash and form a sulphate. When Messrs. Knox, Tennent, and Macintosh established their works at St. Rollox, they separated the sulphur from the saltpetre; the sulphur was burnt over a stove, and an iron cup, containing the requisite quantity of saltpetre, mixed with the requisite quantity of sulphuric acid, was placed over the burning sulphur. By this contrivance the sulphur was completely converted into sulphurous acid, and the whole of the nitric acid carried along with it into the leaden chambers. The size of the leaden chambers was gradually increased, and the substitution of steam for the water formerly placed at the bottom of the chambers, was a vast improvement. The acid which collects at the bottom of the chambers has now a specific gravity of 1·75, or it is a compound of one atom anhydrous acid, and two atoms water. This acid is concentrated by heating it in a platinum still till the second atom of water is driven off. When this manufacture is at full work, the quantity of sulphuric acid made in it exceeds 300,000lbs. avoirdupois per week. When he first began to purchase sulphuric acid, about forty-five years ago, it cost 8d. per pound; the present price is under a penny a pound.

3. One of the great purposes to which sulphuric acid is applied at St. Rollox, is the manufacture of *bleaching powder*, *or chloride of lime*, as it is now called. When the mode of bleaching by chlorine was introduced into Great Britain, by Mr. Watt, in 1787, the very offensive smell and deleterious effects of that gas upon the workmen, was a formidable objection to its use. Various methods were tried to remove this objection. It was found that if potash or soda was dissolved in the water before it was impregnated with the chlorine gas, the disagreeable smell was destroyed; but, unfortunately, this addition destroyed at the same time the bleaching power of the gas. At last, Messrs. Knox, Tennent, and Macintosh discovered that if lime were mixed with the water before it was mixed with the gas, the disagreeable smell was

obviated, while the bleaching power still remained uninjured. They took out a patent for this discovery; but it was infringed upon by the Lancashire bleachers; a law-suit was the consequence, and the patent was destroyed. It was then that Mr. Macintosh tried whether chlorine would not be absorbed by slacked lime. The trial succeeded: a compound was formed, which readily dissolved in water, and the solution of which possessed great bleaching power; a patent was taken out for the manufacture of this dry powder, which the patentees distinguished by the name of bleaching powder. This patent was not infringed; the sale of it was at first small, and it was overlooked by the bleachers. The consequence was, that the patentees had leisure to perfect their method of preparing it, and to become able to sell it at so low a price, that it gradually superseded all the old methods of bleaching by chlorine. The process may be seen at St. Rollox in great perfection, and on a very large scale. The requisite mixture of common salt, binoxide of manganese and sulphuric acid, is put into a leaden still, and the chlorine evolved passes through leaden tubes into air-tight stone chambers, the bottoms of which are covered with a stratum of slacked lime several inches thick. The lime absorbs the gas as it passes into the chamber, and the process is continued till the absorption is reckoned sufficient. Bleaching powder, supposing it pure, is a compound of

1. Chloride of calcium	7
2. Chlorite of lime	10
3. Water	3·375
	20·375

Half the lime loses its oxygen, and combines with chlorine, constituting chloride of calcium. The oxygen combines with chlorine, which, in the state of chlorous acid, combines with the other half of the lime, constituting chlorite of lime. Two atoms of the water were in the slacked lime. The third atom must have come along with the chlorine gas, or been absorbed from the atmosphere.

4. After the chlorine has been extricated, there remains in the still a semi-liquid mass, consisting partly of the impurities of the manganese, and partly of sulphate of soda and sulphate of manganese. If the manganese were pure binoxide, and only the quantity of salt and sulphuric acid necessary for the decomposition were used, the sulphate of manganese (abstracting the water) would weigh nine and a half, and the sulphate of soda nine. But in order to save the stills by producing the decomposition with little heat, twice as much sulphuric acid is used as is necessary, and this excess is afterwards saturated by means of common salt; so that the quantity of sulphate of soda in the residue is at least twice as great as that of the sulphate of manganese. To get rid of the sulphate of manganese, the residue from the stills is fused in a reverberatory furnace at a red heat; this drives off the sulphuric acid, and leaves the manganese in the state of sesquioxide. The whole is dissolved, and the insoluble manganese thrown away. The solution of sulphate of soda is evaporated to dryness, mixed with small

coal, and fused again. This destroys the sulphuric acid, and converts the soda into sulphuret. This sulphuret being mixed with sawdust, &c., and exposed to an incipient red heat, the sulphur is driven off, and carbonate of soda remains, which is obtained in crystals by solution and crystallization, or in the state of *soda ash*, by a more rapid process. The theory of the last step of the process, in converting the sulphate of soda into carbonate, is not very obvious, and would require an experimental investigation to throw light on it.

5. Another chemical manufacture, which may be seen, is *alum-making*. There are two establishments, one at the Hurlet, about six miles south-west, by the Paisley canal; another at Campsie, about eight miles off, near Kirkintulloch, on the Great Canal, and near the foot of the Campsie hills. The alum is made from the *shale*, which exists in great abundance in the exhausted coal beds. This shale is a clay mixed with some coal, and with that variety of iron pyrites, which undergoes decomposition, and is converted into sulphate of iron by exposure to the air. The sulphate of iron, thus formed, acts slowly on the clay, and in process of time converts it into sulphate of alumina. The alum-maker washes this altered shale, and obtains a solution of sulphate of iron and sulphate of alumina. When sufficiently concentrated and cooled, the liquor yields an abundant crop of sulphate of iron, which is removed, dried, and sold at a cheap rate. The sulphate of alumina does not crystallize till it is mixed with sulphate of potash or sulphate of ammonia; because alum is a double salt, composed of three atoms of sulphate of alumina and one atom of sulphate of potash, or sulphate of ammonia. Formerly, nothing but chloride of potassium, bought from the soap-makers, was used. But of late years (at least at Hurlet), sulphate of ammonia, from the liquor obtained during the preparation of gas, has been employed. In general, the alum made at Hurlet contains both potash and ammonia; but the manufacturer can supply it free from potash. Such alum is convenient to chemists, because when it is heated to redness, everything is driven off except pure alumina. At Hurlet and at Campsie the mode of concentrating the liquid by a current of heated air passing over its surfaces, deserves attention.

6. At Campsie alum-works may be seen another interesting chemical manufacture, the fabrication of prussiate of potash, a beautiful well-known yellow salt, which crystallizes in truncated octahedrons. It was here that the manufacture of this salt, on a great scale, first began. Before that time it was only prepared in laboratories for scientific purposes, and sold at a high price. Mr. Macintosh introduced it to the calico-printers, who used it extensively, to produce very beautiful blues and greens. It is prepared by burning the hoofs and horns of cattle in iron pots, along with a quantity of potash. The hoofs and horns of a hundred head of cattle are consumed every day in the works. For some time no iron was added, the requisite quantity for forming the salt being corroded from the pots during the combustion. But the last time that the author visited the works, he found that iron was mixed with the hoofs, &c. during the combustion. The

residue, after this combustion is lixiviated with water, and when the solution is sufficiently concentrated, the prussiate of potash crystallizes. Connected with this manufactory of prussiate of potash is another, of Prussian blue. It is made by mixing sulphate of iron, alum, and prussiate of potash, and precipitating the whole by an alkali. The precipitate is at first light blue. But it is washed with new portions of water every day for several weeks. At every washing the colour deepens, and when it has acquired the requisite shade, the Prussian blue is allowed to subside, the water is drawn off, and the powder allowed to dry. The colour varies according to the proportion of alum employed; and it has the finest colour of all, with the coppery lustre which is so much admired, when no alumina whatever is mixed in it.

7. Another beautiful chemical product may be seen at Shawfield, near Rutherglen, about two miles from Glasgow, in the manufactory of Mr. White. This is *bichromate of potash*, a salt very much used by calico-printers, and forming the finest and most indelible yellows, oranges, and greens. Its introduction constituted quite an era in calico-printing. This salt was originally made by heating chromiron ore with saltpetre, dissolving out the chromate of potash, and adding the requisite quantity of nitric acid to deprive the chromic acid of half its potash. When this process began, the salt was sold at a guinea an ounce; but now, when the price is as low as two shillings a pound, it is necessary to prepare it by a cheaper method. It has been found that common potash of commerce may be substituted for saltpetre; and Dr. Thomson believes the manufacturers now contrive to form the bichromate at once, without requiring the use of an acid, which would nearly double the expense. It is stated that all the bichromate used by the calico-printers is made here and in Liverpool. In the same manufactory may be seen a beautiful product, tartaric acid, which is used by the calico-printers to a large amount, chiefly to disengage the chlorous acid from bleaching powder, and enable it to destroy the colour on particular parts of the cloth, either that these parts may remain white, or that some other colour may be superadded. Tartaric acid is obtained from cream of tartar, by throwing down the tartaric acid by means of lime, and afterwards decomposing the tartrate of lime by means of sulphuric acid, and crystallizing the tartaric. At the same manufactory may be seen a pretty and simple process, by which the carbonate of soda is converted into the sesquicarbonate. By simply exposing it dry, and in powder, in an atmosphere of carbonic acid gas, it absorbs the requisite quantity to be converted into sesquicarbonate. And this sesquicarbonate is chiefly used by the makers of soda water.

8. It is hardly proper to mention the manufactory of acetic acid from wood, which has been carried on for many years by Mr. Turnbull, because the first part of the process is carried on at a distance, the distillation of the wood. To free the acetic acid from the tar, which destroys its flavour and taste, the acid is combined with lime, and the acetate of lime exposed to a heat sufficiently high to char the

foreign bodies with which it is impregnated, the acetic acid being capable of resisting a higher temperature without decomposition than most compound vegetable bodies. The acetate of lime thus purified is decomposed by sulphuric acid, and the acetic acid obtained by distillation. By this process it may be obtained very strong. The author possesses it composed of one atom acetic acid, and one atom water. When of this strength it crystallizes in winter, but becomes liquid again in summer. In the same manufactory there is another liquid prepared, namely, *pyroxylic spirit*, now well known. A most interesting set of experiments on it has been made by Dumas, who has distinguished its basis by the name of *methylene*, and has discovered various new compounds which it is capable of forming.

9. Another chemical manufacture of considerable importance, and which the author believes to be peculiar to Glasgow, is *iodine*. A few years ago there were no fewer than ten manufactories, in each of which it was made to a considerable extent; but as iodine is only used in medicine, the sale is necessarily limited, and most of these works are now abandoned. The process followed by all the makers was, Dr. Thomson believes, the contrivance of Mr. Macintosh. Iodine is made from kelp, and it deserves attention, that those kinds of kelp that contain most potash, contain, at the same time, the most iodine. The kelp is lixiviated, and all the salts that can be extracted from the solution by evaporation are separated. The mother water remaining is now mixed with an excess of sulphuric acid. A great quantity of sulphuretted hydrogen is evolved, the bad effects of which on the workmen are obviated by setting it on fire, and allowing it to burn as it is extracted from the liquid. To the liquid thus freed from sulphuretted hydrogen and from muriatic acid, a quantity of binoxide of manganese, equal in weight to the sulphuric acid employed, is added. The whole is put into a leaden still, and heated to a temperature which must not exceed 190° or 200° at most. The iodine passes into the receiver, which consists of a series of spherical glasses, having two mouths opposite to each other, and inserted the one into the other.

10. It may seem superfluous to mention *soap*, because it is a manufacture universally known; but soap of a very superior quality is made in Glasgow. The number of soap-works amounts to seven, and one of these, that at St. Rollox, is the third, if not the second, in point of extent, in Great Britain. The ingredients of soap are soda, tallow, and rosin, and sometimes palm-oil. Two kinds only of hard soap are made here, namely, *yellow* and *white*. The yellow soap is made by boiling 9·75 cwt. of tallow, 3·25 cwt. of rosin, 4 cwt. of soda ash, equivalent to 2 cwt. soda, mixed with the requisite quantity of water; the white, by boiling 13 cwt. of tallow, 4 cwt. of soda ash in the same manner. Tallow, which is a compound of two oily acids and glycerine, undergoes decomposition, and the soda combines with the acid and forms soap. When the combination is complete, a quantity of common salt is put into the hot liquor. It dissolves in the water, and the soap separates, and swims on the top. It is now allowed to cool to 150° at an average, and then taken out in a liquid state, and poured into

frames, where it is allowed to become solid, and then cut into the usual parallelopipeds, or wedges, as they are called. It is customary, during the *cleansing* of the soap, as the pouring it into the frame is called, to mix it with a quantity of caustic soda ley. The soap made in Glasgow is usually a compound of

1 atom oily acid......	53	or per cent.	74·6
2 atoms soda	8	„	11·2
9 atoms water	10·125	„	14·2
	71·125		

White soap is cleansed at the average temperature of 181°. Its constitution is precisely the same as that of yellow soap.

11. Bleaching of cotton cloth is carried on here to a great extent. It consists of four processes:—1st. The goods are boiled with lime, at a temperature above the boiling point of water. The process is curious, and deserves to be seen. 2nd. The cloth is steeped in a solution of bleaching powder. 3rd. It is boiled with caustic soda or potash. 4th. It is steeped in water acidulated with sulphuric acid.

12. Turkey-red dyeing has been practised here for almost half a century.

13. *Calico-printing* is carried on here to a great extent; *glass-making* is carried on here or on the Clyde in all its branches; for *starch-making* there is only one manufactory. The manufacture of the dye stuff called cudbear, employed in dyeing red, has long been carried on here; so has the distillation of spirits and the manufacture of æther.

On the Minerals in the Neighbourhood of Glasgow. By Professor THOS. THOMSON, *F.R.S.*

The neighbourhood of Glasgow, including Lead Hills, is not even inferior to Cornwall in the richness of its mineral species. The mines at Lead Hills began to be wrought during the reign of James IV. under the name of gold mines, and it is said by Boethius that he extracted from them a considerable treasure. In the time of James V. Lead Hills was a lead mine as at present, and is particularly described by Agricola in his celebrated work *de re metallica*. Besides galena, no fewer than nine species of lead ore occur at Lead Hills; these are—

1. Sulphate of lead. 2. Carbonate of lead, analysed by Klaproth in 1802. 3. Cupreo-sulphate of lead, described by Mr. Sowerby. 4. Sulphato-carbonate of lead, analysed by Mr. Brooke in 1820. 5. Sulphato-tricarbonate of lead, analysed by Mr. Brooke in 1820. 6. Phosphate of lead, analysed by Dr. T. Thomson. 7. Cupreo-sulphato-carbonate of lead, analysed by Mr. Brooke in 1820. 8. Chromo-phosphate of lead, analysed by Dr. T. Thomson. 9. Vanadiate of lead, analysed by Dr. R. D. Thomson in 1834.

Lead Hills also affords fine specimens of blende, or sulphuret of zinc, and also of silicate of zinc.

In Kilpatrick, hills, which bound the valley of the Clyde from the Stockey Muir to Dumbarton, and also the corresponding but lower

range on the south side of the valley, are composed of various trap-rocks, among which amygdaloid is pretty common. The cavities of this rock are filled up by crystallized minerals, most of them zeolites; these are—

1. Stellite, first analysed by Dr. T. Thomson and Dr. R. D. Thomson. 2. Thomsonite, named by Mr. Brooke after Dr. T. Thomson. 3. Natrolite. 4. Mesolite. 5. Scolezite. 6. Laumonite. 7. Chabazite. 8. Analcime. 9. Cluthalite, first analysed by Dr. T. Thomson and Dr. R. D. Thomson. 10. Stilbite. 11. Heulandite. 12. Harmotome or Cross stone. 13. Carbonate of magnesia, at Bishoptown. 14. Dihydrous peroxide of iron, at Gourock. 15. Sulphate of barytes. 16. Calcareous spar. 17. Fibrous sulphate of lime. 18. Arragonite. 19. Wollastonite, first analysed by Dr. T. Thomson and Dr. R. D. Thomson. 20. Prasolite, named by Dr. T. Thomson. 21. Fluor spar. 22. Prehnite. 23. Augite. 24. Amphibole. 25. Felspar. 26. Labradorite, one of the constituents of a variety of greenstone at Campsie glen, and at Gleniffer. 27. Mica. 28. Epidote. 29. Steatite. 30. Iron pyrites. 31. Carbonate of iron. 32. Gray ore of manganese. 33. Kilpatrick quartz, first analysed by Dr. T. and Dr. R. D. Thomson. 34. Sulphuret of cadmium, rare, and lately discovered, occurring along with prehnite at Bishoptown. Single crystals are now selling at 10*l*. each. It has been analysed by Dr. T. Thomson and Mr. Connel.

On the Relation of Form to Chemical Composition. *By Dr.* Schafhaeutl.

The author stated, that he had, in a former communication, given a new method of procuring graphite, in which it was also shown that all graphites owed their origin to the operation of the same causes; namely, the contact of bitumen (or any similar substance) with a silicate, under a certain limited degree of heat; it was further maintained, that the compound nature of graphite might be satisfactorily demonstrated, by subjecting it to the action of hydrofluoric acid, which, combining with the silicon, liberated the carbon of the graphite as a hydruret, which was then consumed in the flame of a lamp. The object of the present paper was to explain the circumstances under which certain modifications of form take place in this peculiar substance (as also in others generally considered to be elementary), and to prove their connexion with changes of an entirely chemical nature.

A beautiful specimen of a formation of graphite was exhibited to the Section, obtained from the Neath Abbey Ironworks, in South Wales; it appeared to be composed of an infinite number of foliated scales overlapping each other, after the manner of the slates of a roof, each scale being so thin, as to be agitated by the slightest breath of air; a second specimen was exhibited of a graphite leaf, where it appeared as a globule of much greater size, the laminated structure still, however, existing in beautiful development. In a third stage, the scaly structure disappeared; the globule having assumed a more porous and coke-like form. Dr. S. having premised an objection to any explanation of these curious changes of form, founded merely upon molecular alterations, proceeded to detail certain experiments, from which he deduced conclusions of an interesting and important nature.

The discovery of a new mode of decomposing crystallized graphite, by heating it in concentrated boiling sulphuric acid, and adding a little concentrated nitric acid*, afforded a series of singular and instructive phænomena. After the evolution of binoxide of nitrogen had ceased, each scale of graphite was converted into the globular substance before described; its external metallic lustre remaining unchanged, but its bulk so greatly enlarged, that what before appeared a single scale, became, by the separation and division of its component laminæ, a thick spongy tissue, capable of being restored to its former compressed foliated form by the pressure of the finger-nail. That this change of form, however, was not merely a mechanical effect, appears from the following experiment:—Graphite scales having been repeatedly treated with hydrochloric acid, washed, and again digested in a strong solution of caustic potash, in order to remove all possible mechanical admixtures of iron, silica and alumina, were then subjected to the process above described; the evolution of binoxide of nitrogen having ceased, an equal quantity of water was added to the mixture; immediately there succeeded a rapid evolution of bubbles from the globules of graphite, which at first lay at the bottom of the fluid; becoming lighter, as this evolution of bubbles proceeded, they gradually rose to the surface, when the gas immediately ceased to be evolved; the acid then, or the graphite, must have been combined with hyponitrous acid, which being decomposed by the water was disengaged as binoxide of nitrogen. The globules when washed, dried, and weighed (at first weighing but 2·01 grs.), *had gained* 5·02 grs. in weight. Being then put into a flat covered dish of brass, and balanced accurately, the cover was removed, the globules immediately lost weight, and so rapidly, that in merely removing them from the dish, 0·18 gr. were lost; the dish was covered with a dew, apparently acid, as it acted on the brass. These globules, heated on paper until it became slightly tinged with yellow by the heat, now disengaged dense fumes, the paper being streaked with a blackish-coloured smoke where it was in contact with the graphite; 2·30 grs. were lost during this process, which being repeated a second time, they were found to have lost 2·25 more. Finally ignited in a platinum crucible, dense fumes, without any perceptible odour, escaped, the weight of the globules being reduced to 1·86 gr. After which, no further reduction took place during the ignition for half an hour in the open air. The total loss of the two grains thus experimented upon with the acid, was 6·96. In a paper by the author†, this loss was attributed to evolution of carbonic acid gas during this conjoined action of the acids; but it would appear from the last experiment, that there is formed a compound of sulphuric acid, nitric acid, carbon, hydrogen and oxygen, volatilized only at high temperatures. The question here arises, how can the rapid loss of weight be accounted for? During the previous drying process, which was conducted at 212°, the loss of water must have been accompanied by a change of chemical composition, and the new compound, by attracting

* See a description in the Philosophical Magazine, vols. xvi., xvii.

† See Philosophical Magazine, cited above.

water or oxygen when in the pan, must have formed an extremely volatile combination, evaporating as rapidly as it was formed. By a repetition of this treatment with the acid, graphite in the third stage, as before described, was obtained; the metallic lustre was entirely lost, as also the laminated texture; it now appearing as a porous mass, resembling coke, and no longer capable of reduction to its original foliated state by pressure, having undergone a decided chemical change. The acid solution deposited at once a copious precipitate of silica and alumina (slightly tinged by oxide of iron), upon the addition of ammonia to neutralization. A similar precipitate was obtained from the acid of the first experiments, but less in quantity, and requiring a longer time for its operation. Thus it would appear that the abstraction of silicon and the change of physical properties of graphite, are corresponding and mutually connected phænomena. In further proof of the necessary connexion of silicon as a chemical combination, essential to the existence of the scaly metallic lustre of graphite, it will be found that by repetition of the same experiments, the globules ultimately disappear, and the remaining solution in acid neutralized by ammonia, deposits only flaky silica, with traces of oxide of iron. On observing attentively the specimen of graphite, as found in its natural state, and comparing it with those treated with acids and alkalies, also exhibited, it appeared that the scales, before being operated on, had a dirty grayish appearance, described as owing to their being covered with spots, consisting of microscopic six-sided flattened prisms of silicate of iron; the matrix of this graphite formation, in the blast-furnace cinder, essentially composed of bisilicate of lime and alumina, deriving a yellowish tint from a slight admixture of sulphuret of calcium, with a trace of sulphuret of potassium. Scales of very different density may be separated, the thinnest unaffected by the magnet, the thicker ones decidedly so; those in the middle of the mass, thicker and stiffer, not easily broken, and showing a shining black fracture, like that of anthracite, form a variety of graphite, in which silicon and iron are greatly predominant, developing when treated with hydrochloric acid a fetid hydrogen characteristic of cast iron, and separating at the same time yellow flocks of silica and alumina. Dr. Schafhaeutl then proceeded to point out an analogy between the formation of gray iron in the blast furnace, and that of graphite; namely, that the same chemical conditions occur during the change of white iron into gray; this takes place after having descended through the furnace, and reached the stratum of slag covering the melted metal; this slag being an earthy bisilicate (in coke furnaces approaching to a trisilicate), and containing a small quantity of protoxide of iron. As silicon is found in graphite only in very small quantity, it has been considered an accidental impurity, just as the small quantity of hydrogen retained by charcoal, sulphur, &c. has been considered an impurity; but as these foreign matters can by no chemical means be separated, without destroying the state in which graphite, charcoal and sulphur exist, it must be inferred that such admixture is essential to their existence in that state in which they ordinarily appear. Quitting now the individual consideration of gra-

phite, the author extended the principle here argued to certain other substances, considered generally as simple bodies. For example, sulphur obtained by the decomposition of sulphurets by acids, is white in colour, and invariably combined with a stable quantity of hydrogen; but obtained from hyposulphites, it is as invariably yellow, and the presence of free hydrogen in the slightest quantity bleaches the precipitate. The known case of sulphur precipitated under the presence of sulphuretted hydrogen, and cautiously mixed with metallic copper in its utmost state of minute division, being found to combine directly, evolving a dull red heat, has been considered an exception to the law, that no two dry bodies unite without the intervention of a third; but sulphur precipitated from hyposulphites, will not thus combine, nor will pure sulphur, though subjected to the minutest division possible. The same sulphur, however, brought into contact with hydrogen, under a pressure of four atmospheres, and then quickly mixed, is found to combine, as in the first instance; but if exposed to the air, its power of combination is again lost; thus a third body is proved necessary here, as in all cases. And further, the author doubted if one of the two different crystalline forms of sulphur is not owing to the presence of hydrogen, which he found to be in combination with it in a very perceptible quantity. These peculiar forms of combination, where a few atoms of one body are combined with a high number of atoms of another, may be considered, perhaps, as forming a class of compounds intermediate between the inorganic and the higher organic compounds: thus the compounds of arsenic acid form a very striking example. In the subarseniate of iron, 50 atoms of iron are combined with only 3 atoms of arsenic acid and 75 of hydrogen. So again, 24 atoms of arsenic with 1 atom of sulphuret of potash in sulph-arseniate of potash. By gradually passing from compounds of inorganic chemistry to those of organic chemistry, we find di-acetate of copper with water, 48 atoms of oxide of copper combined with only 1 atom of hydrogen and 12 atoms of water. And finally, in the field of organic chemistry itself, we have, for example, margaric acid, composed of 67 atoms of hydrogen, 35 carbon, and 3 of oxygen only. In the oleic acid, 120 atoms of hydrogen are combined with 70 of carbon and 5 of oxygen; in the stearic acid, 134 atoms of hydrogen with 70 of carbon and 5 of oxygen, &c. The author hinted in his paper in the Philosophical Magazine, that the principal circumstance which tended to produce compounds of such multiplicity of atoms, or, in fact, organic compounds, was the separation of the molecules of bodies brought into action by the capillary powers of the vessels of organic structures. It was probable that the chemical action of these separated molecules must be a different one from their action, when arranged into one definite form; and as proof that once-received laws of affinity were exhibited only under peculiar circumstances, he directed the attention of the Section to H. Rose's compound, formed by direct combination of 29·97 per cent. of ammonia with 70·03 per cent. of sulphuric acid, which ought to have produced anhydrous sulphate of ammonia; but after combination, neither sulphuric acid nor ammonia could be detected in the compound. The same chemist found

combinations of anhydrous sulphuric acid with the chlorides of ammonium, potassium, sodium, and the nitrate of potash. According to the laws of affinity, for example, in the last case, the nitric acid ought to have been displaced, decomposed, and driven away by the more powerfully acting sulphuric acid; but no tendency whatever was shown to the displacement of chlorine or nitric acid, and new compounds, different from all hitherto known, resulted. As no combination of anhydrous sulphuric acid took place at all with oxide of calcium, chloride of barium, or chloride of copper, he concluded that these above-mentioned combinations were formed only by replacing one double atom of hydrogen, water, or chlorine, in order to form a bisulphate of potash, soda, or ammonia. The author seemed to believe that there existed two different states of chemical combination; the first, in which the chemical forces of molecular attraction were acting only according to the relative quantities of matter; the second, where, under the always catalytic presence of a third, the elementary substances arranged themselves, separating in groups according to the resultant electric forces of the centres of action created by the above-mentioned presence of a third, acting differently on the different molecules of bodies in contact, in a somewhat similar way as a solution, which does not crystallize unless the molecular equilibrium of the liquid is disturbed. The first state of chemical combination might, perhaps, have some distant relation to Dumas's law of types; the second state, a mere consequence of the first, would be represented by Berzelius's electro-chemical combination. The author, at the same time, referred to Prof. Graham's admirable papers, in which the Professor had so distinctly pointed out the great and *peculiar* part which water performs in chemical solid combinations, and remarked, that during all chemical combinations where a third body is separated, the precipitation only would take place when a certain quantity of water combined with the body to be precipitated, which water separated in the relation to the separation and consolidation of the precipitate only, and could be driven away from it only by applying a red heat.

New Compound of Arsenious and Sulphuric Acids. By Dr. Schafhaeutl.

This was obtained from the escaping smoke of copper calcining furnaces near Swansea, in South Wales. The new compound was another singular instance where an anhydrous crystallized body was deposited under the presence of water only, and was a remarkable proof of the unlimited number of different forms of combination, which might be produced even in inorganic nature, by bringing chemical substances in contact under varying circumstances. The copper ores smelted in South Wales were, for the greatest part, copper pyrites, mixed with iron pyrites, gray copper ore, &c.; in fact, a mixture in which the sulphurets of copper, iron, arsenic, antimony, cobalt, nickel, zinc, and tin were invariably found together. The sulphur and arsenic escape from these ores during the calcining process, as

sulphurous and arsenious acids, and have been found to destroy all vegetation for miles around the copper works, without affecting animal life in the slightest degree. By bringing the escaping fumes in contact with steam, and forcing it through burning charcoal, or subjecting it only to a great pressure in contact with steam, the new solid compound was deposited on the cool surfaces of the chambers connected with the calcining furnace. It was deposited in beautiful crystallized leaves or tables, perhaps belonging to the same class as Wöhler's dimorphic modification of the crystallization of arsenious acid, the regular form of which belongs to the octahedron. It was found to consist, in 100 parts,

of 68·250	Arsenious acid.
27·643	Sulphuric acid.
3·029	Protoxide of iron.
0·420	Oxide of copper.
0·656	Oxide of nickel.
99·998	

Corresponding to	51·741	Metallic arsenic.
	11·095	Sulphur.
	2·339	Iron.
	0·336	Copper.
	0·516	Nickel.
	33·971	Oxygen.
	99·998	

These crystals attracted moisture from the air with great rapidity and with evolution of heat, corroding animal and vegetable substances as powerfully as concentrated sulphuric acid. Their taste was pure, but powerfully sour, similar to sulphuric acid, and, dissolved in water, the remainder of 100 parts of these crystals was 17·436 grains only. The shape of the crystals was perfectly retained, only their appearance was changed from transparent into opake. Their chemical composition was found to be,

16·778	grains of Arsenious acid.
0·656	Oxide of nickel.
17·434	

What the water had dissolved consisted of

51·472	Arsenious acid.
27·643	Sulphuric acid.
3·029	Protoxide of iron.
0·420	Oxide of copper.
82·564	grains.

One of the remarkable changes during the formation of this compound, was the conversion of sulphurous acid into sulphuric acid, as well as the presence of iron, copper, and nickel in a deposit from gaseous matter. No other definite compound of arsenic acid with another acid seems to be known, except those with the organic tartaric and paratartaric acids.

On a New Method of Photogenic Drawing. By Dr. SCHAFHAEUTL.

After some observations on the comparatively low value of all drawings taken by means of the camera-obscura, in an artistical point of view, and on the principal points on which Mr. Talbot's and M. Daguerre's methods of fixing the drawings of the camera-obscura were founded, the author proceeded to describe his peculiar methods of producing photogenic drawings in Mr. Talbot's, that is, in a negative way; then, secondly, he described two new methods of obtaining photographs in a *positive* way. His first method tended to obtain a paper of very great sensibility by a comparatively short process. He recommended Penny's improved patent metallic paper, and spreading a concentrated solution of the nitrate of silver (140 grains to $2\frac{1}{2}$ drachms of fused nitrate to six fluid drachms of distilled water), by merely drawing the paper over the surface of the solution contained in a large dish. In order to convert this nitrate of silver into a chloride, the author exposed it to the vapours of boiling muriatic acid. A coating of a chloride of silver, shining with a peculiar silky lustre, was by this method generated on the surface of the paper, without penetrating into its mass; and in order to give to this coating of chloride the highest degree of sensibility, it was dried, and then drawn over the surface of the solution of the nitrate of silver again. After having been dried, the paper was ready for use; and no repetition of this treatment was able to improve its sensitiveness. The author's process for fixing definitively the drawing was as follows:—He steeped the drawing from five to ten minutes in alcohol, and after removing all superfluous moisture by means of blotting-paper, and drying it slightly before the fire, the paper thus prepared was finally drawn through diluted muriatic acid, mixed with a few drops of an acid nitrate of quicksilver, into the minutiæ of the preparation of which we cannot here enter. The addition of the nitrate of mercury requires great caution, and its proper action must be tried first on paper slips, upon which have been produced different tints and shadows by exposure to light; because, if added in too great a quantity, the lightest shades disappear entirely. The paper, after having been drawn through the above-mentioned solution, is washed well in water, and then dried in a degree approaching to about 158° Fahr., or, in fact, till the white places of the paper assume a very slight tinge of yellow. The appearance of this tint indicates that the drawing is fixed permanently. The author's way for reversing the drawing is, in the principal points, the same as that suggested by Mr. Fox Talbot.

In order to obtain a photogenic drawing in a direct or positive way, the author uses his above-mentioned paper, allows it to darken in a bright sunlight, and macerates it for at least half an hour in a liquid, which is prepared by mixing *one part* of the already described acid solution of nitrate of mercury with from nine to ten parts of alcohol. A bright lemon-yellow precipitate, of basic hyponitrate of the protoxide of quicksilver, falls, and the clear liquor is preserved for use. The macerated paper is removed from the alcoholic solution, and quickly drawn over the

surface of diluted hydrochloric acid (one part strong acid to seven or ten of water), then quickly washed in water, and slightly and carefully dried in a heat not exceeding 212° of Fahr. The paper is in this state ready for being bleached by the rays of the sun; and in order to fix the obtained drawing, nothing more is required than to steep the paper a few minutes in alcohol, which dissolves the free bichloride of mercury. The maceration must not be continued too long, as in that case the paper begins to darken again.

The author's second method of producing positive photogenic drawings was by using metallic plates, and covering them with a layer of hydruret of carbon, prepared by dissolving pitch in alcohol, and collecting the residuum on a filter. This, when well washed, is spread as equally as possible over a heated even metallic plate of copper. The plate is then carbonized in a close box of cast iron, and, after cooling, passed betwixt two polished steel rollers, resembling a common copperplate printing-press. The plate, after this process, is dipped into the above-mentioned solution of the nitrate of silver, and instantly exposed to the action of the camera. The silver is, by the action of the rays of the sun, reduced into a perfect metallic state, the lights are expressed by the different density of the milk-white deadened silver, the shadows by the black carbonized plate. In a few seconds the picture is finished; and the plate is so sensitive, that the reduction of the silver begins even by the light of a candle. For fixing the image, nothing else is required, except dipping the plate in alcohol mixed with a small quantity of the hyposulphite of soda, or of pure ammonia.

On Poisons, Contagions, and Miasms. By Professor Liebig.

Dr. Playfair stated that he had prepared, at the request of the author, a statement of Professor Liebig's new views on the subject of poisons. Poisons might be divided into two classes, belonging to the inorganic and organic kingdoms. Many substances were called inorganic poisons which had in reality no claim to be considered as such. Sulphuric, nitric, and muriatic acid, when brought in contact with the animal œconomy, merely destroyed the continuity of the organs, and might be compared, in their *modus operandi*, to the action of a heated iron, or a sharp knife. But there are others—and these are the true inorganic poisons—which entered into combination with the substance of the organs without affecting any visible lesion of them. Thus it is known, that when arsenious acid or corrosive sublimate is added to a solution of muscular fibre, cellular tissue, or fibrin, these enter into combination with them, and become insoluble; when they are introduced into the animal organism the same circumstance must happen. But the bodies formed by the union of such poisons with animal substances are incapable of putrefaction; they are incapable, therefore, of effecting and suffering changes; in other words, organic life is destroyed. The high atomic weight of animal substances explains the cause of such small quantities being requisite for producing deadly

effects. After stating several chemical details on this subject, it was shown that to unite with 100 grains of fibrin, as it exists in the human body (in which it is combined with 30,000 parts of water), only $3\frac{3}{4}$ grains of arsenious acid are necessary, or 5 grains of corrosive sublimate.

The second class of poisons were those belonging to the organic kingdom. For some such substances as brucia and strychnia, no data exist by which it can be determined to what cause their action may be assigned. But the morbid poisons, such as putrid animal and contagious matter, appear to owe their action to a peculiar agent, which exerts a much more general and powerful action than chemists are aware of. Thus, when oxide of silver is thrown into peroxide of hydrogen, the oxide is reduced and metallic silver remains. Here there can be no affinity, for oxygen can have no affinity for oxygen. It is merely that a body in a state of motion or decomposition is capable of inducting or imparting its own state of motion or decomposition to any body with which it may be in contact. There is a disease frequently produced in Germany by using decayed sausages as an article of food. The symptoms attending the disease are remarkable, and distinctly indicate its cause. The patient afflicted with the disease becomes much emaciated, dries to a complete mummy, and finally dies. The muscular fibre, and all parts similarly composed, disappear. The cause of the disease evidently is, that the state of decomposition in which the component parts of the sausages are, is communicated to the constituents of the blood, and this state not being subdued by the vital principle, the disease proceeds until death ensues. It is remarkable that the bodies of the individuals who have died in consequence of it are not subject to putrefaction.

The cause of the action of contagious matter is similar. It is merely a gaseous matter in the state of transformation, and capable of imparting the state of transposition in which its atoms are to the elements of the blood. It is capable of being reproduced in the blood just as yeast causes its own reproduction in fermenting *wort.* The causes of the action of yeast and of contagion were shown to be the same, and examples were produced in which similar reproductions take place in common chemical processes. There are two kinds of yeast used in the brewing of Bavarian beer. The fermentation caused by one is tumultuous, that produced by the other is tranquil. They, therefore, induct the peculiar state of transposition in which their atoms are upon the elements of the sugar. The same was shown to be the case with the vaccine virus of cow- and small-pox; the one of which produces a violent action upon the constituents of the blood, whilst the other causes a gentle action quite distinct from the former.

On the Pre-existence of Urea in Uric Acid. By Professor Gregory.

By the action of peroxide of lead on uric acid, Liebig and Wöhler obtained from it oxalic acid, allantoine and urea; and they considered the latter as existing in the uric acid combined with urile. The author,

having found that urea, unlike most organic substances, resists the oxidizing agency of permanganate of potash, thought that if urea could be obtained from uric acid by the action of that salt, the argument for its pre-existence would be much strengthened; as, if only the elements of urea were present, the oxidizing agency of the permanganate would most likely prevent its formation. On trying the experiment a large quantity of urea was obtained, along with oxalic acid, and a new acid, probably formed by the oxidation of allantoine. The author further described the acetate of urea, a salt which was formed in his experiments.

On a New Process, communicated by Prof. Liebig, for preparing Murexide. By Professor GREGORY.

The process described in this communication for preparing the very singular and beautiful compound, termed murexide by Liebig and Wöhler, and purpurate of ammonia by Prout, is quite certain, and very productive. It consists in adding a boiling solution of seven grains of alloxan and four grains of alloxantine in 240 grains of water, to 80 grains of a cold and strong solution of carbonate of ammonia. The mixture instantly acquires a deep purple colour, and on cooling deposits the golden-green crystals of murexide.

On the Preparation of Alloxan, Alloxantine, Thionurate of Ammonia, Uramile, and Murexide. By Professor GREGORY.

To prepare alloxan from uric acid, Liebig and Wöhler used nitric acid, sp. gr. 1·42, and separated the acid liquid from the crystals by means of a porous brick, thus losing the whole mother liquid. The author uses nitric acid of sp. gr. 1·35. The action of this acid on uric acid must be kept moderate. When crystals of alloxan are formed, the whole is thrown on a filter, the throat of which is stopped with asbestus. That portion of the acid liquid which remains in the crystals is displaced by a few drops of cold water, and the crystals are purified by re-crystallization. The liquid is again employed in the same way, and the crystals are collected as before. Five such operations may be performed with the same liquid, each yielding a large crop of crystals; while the mother liquid is preserved, and yields a large quantity of parabanic acid, or oxalurate of ammonia. By this process the author obtains from 100 parts of uric acid, 65 of anhydrous alloxan, or 90 of alloxan + 6 aq. From alloxan, alloxantine is easily obtained by the action of sulphuretted hydrogen. Thionurate of ammonia is easily formed, by boiling a solution of alloxan with sulphite of ammonia and free ammonia. Uramile is also easily obtained, by boiling a solution of thionurate of ammonia with an excess of diluted sulphuric acid. Murexide is obtained, as described in another communication by Prof. Gregory. He now exhibited the last three processes. He also stated, that the theory of the formation of murexide was of great importance in reference to organic colouring matters.

Process for Preparing Hydrobromic and Hydriodic Acids. By Dr. R. W. Glover, *of Newcastle.*

Dr. Glover having observed that the solid bromide and iodide of barium are decomposed by sulphuric acid, with the evolution of hydrobromic and hydriodic acids, without bromine or iodine being set free, proposed the employment of these salts of barium as very convenient sources of the above-named hydracids in atomic proportions.

On a Method of separating, by Filtration, the Coagulable Lymph from Liquid Human Blood. By Prof. Andrew Buchanan.

Dr. Buchanan showed several specimens of coagulable lymph separated by filtration from human blood while yet liquid, immediately after issuing from the vein. He thought the process for obtaining it might not be without interest to those engaged in the prosecution of animal chemistry, as it enabled them to obtain the fibrin of the blood in a perfectly pure state; and he knew no other process by which it could be so procured. The result obtained was also interesting, as serving to illustrate the constitution of the blood itself. It showed the coagulum to be formed not by the mere aggregation of the red particles, but that, according to the views of Berzelius, and many physiologists in our own country, the red particles were altogether passive in the act of coagulation, and were merely mechanically enveloped by the coagulable lymph, which existed in the liquid state in the blood as it circulates in the blood vessels. Dr. Buchanan's process consisted in mingling together one part of liquid blood just drawn from the vein with six or eight parts of perfectly pure serum obtained from blood drawn the day before. Certain precautions are indispensable to the success of the experiment. If the blood be at once mixed with the whole of the serum, the red particles of the blood pass through the filtering paper along with the lymph and serum. Advantage must be taken of the superior specific gravity of the red particles in order to separate them. For this purpose, the liquid blood mixed with only a small quantity of serum is cautiously added to the rest of the serum placed in the funnel. The red particles subside, while the lymph mingles with the serum, and filtrates perfectly pure through the layer of red particles at the bottom, just as we filter any liquid through a stratum of sand. The mutual action of serum and liquid blood has not been sufficiently investigated. It has, indeed, been long known to physiologists, that the serum of the blood has no action upon the red particles, and they have employed it in their examination of the red particles under the microscope. They do not, however, appear to have pursued the inquiry further, to ascertain what becomes of the "liquor sanguinis," as it has been called, the transparent part of the blood as seen by the microscope, and of the fibrin which it holds in solution. To ascertain this, various proportions of serum and liquid blood were mingled together. When equal measures of the liquids were used, or two or three parts of serum to one of blood, the coagulum formed was merely more voluminous and

looser in texture than usual, but not otherwise altered in appearance. When, however, six or eight parts of serum are employed, the coagulation is much retarded, the red particles form a dense layer at the bottom of the vessel, while the whole fibrin coagulates alone, forming a voluminous translucent mass,—an artificial "buffy coat," as it would be called by physicians. In this way, however, the fibrin is not obtained pure, but has more or less of a red tinge, particularly in the lower half of the mass, owing to the red particles not having completely subsided before the coagulation took place. The results corresponded to what the author had anticipated, but he had no expectation of being able to obtain the fibrin perfectly pure by filtration, as Müller had done with respect to the blood of the frog. Of the four specimens exhibited by Dr. Buchanan, one consisted of the red particles gradually deposited, while the fibrinous coagulum, with only a slight tinge of red at its lower part, floated above; the other three consisted of fibrin separated by the filter, one of the masses floating in serum, the other two in water. These masses are very like calf-foot jelly in appearance. They are of a cellular texture, and their yellow colour is owing to the serum contained in their meshes, but by ablution with water they become of a pure white colour.

On the Constitution and Products of the Distillation of Fat Bodies. By Professor REDTENBACHER *and Dr.* VARRENTRAPP.

The object of this paper was to show that the composition of the fat acids has hitherto been erroneously stated. A variety of acids were subjected to examination, such as stearic, margaric, oleic and sebacic acid. Margaric and stearic acids were shown to possess the same radical; the former being the higher, the latter the lower oxide of it. This radical has the formula of $C_{34}\ H_{33}$, and may be represented by the symbol $\overline{Ma}$; thus stearic acid is $2\ Ma + 5\ O$, whilst margaric acid is $1\ Ma + 3\ O$. They thus resemble sulphuric and hyposulphuric acids. Margaric acid is one of the products of the distillation of stearic acid; the oxidation of the latter also causes the formation of the former. Oleic acid was analysed by these gentlemen, having been obtained in a pure state. The results were principally numerical, and are stated in Liebig's Journal for 1840.

On a New Fat Acid. By Dr. L. PLAYFAIR.

Dr. Playfair had examined some of the vegetable fats, for the purpose of ascertaining whether the margaric acid contained in them possessed a constant composition. He remarked that the acid in the butter of nutmegs was peculiar, and had not formerly been examined. Pelouze and Bondet have stated in the *Annales de Chimie*, that it is margaric acid. Dr. Playfair considered that the radicals of serecic and œnanthic acid were similar; in the former, however, one equivalent of

hydrogen is replaced by one equivalent of oxygen. It is a beautiful white crystalline compound melting at 49° c., and is soluble both in alcohol and æther. The combination of the acid with oxide of glyceril exists in the butter; it unites with metallic oxides and forms salts: these were described, but the results are not susceptible of analysis, as they were principally numerical. The formula of the acid is $C_{28}\,H_{54}\,O_3$.

On a New Mode of estimating Nitrogen in Organic Analysis. By Professor Bunsen, *of Marburg.*

The qualitative methods at present employed for the analysis of azotized bodies were shown to be defective; for it is impossible to employ these processes when the nitrogen and the carbon are in small proportions to each other. Professor Bunsen's process consists in introducing the substance to be analysed, after having mixed it with oxide of copper, into a glass tube. A few slips of metallic copper are then added, and the tube is fixed to Dobereiner's apparatus for producing hydrogen. This gas is conducted through it until all the atmospheric air is expelled, the tube having given to it a rotatory motion at the same time, in order to dislodge any air which might be retained between the particles of the oxide of copper. The tube is now hermetically sealed, and introduced into an iron vessel filled with gypsum. The gypsum must be still moist when the tube is introduced, in order that it may be firmly wedged. Thus prepared, it is introduced into the common oven used for organic analysis, and surrounded with red-hot coals. If the tube be of strong green glass it never bursts. When the combustion is completed the tube is placed below a graduated glass receiver standing over mercury, and the point cut off. The gas, which had a pressure of several atmospheres, now rushes into the jar. The carbonic acid is absorbed by a ball of hydrated potash, which is introduced into it, and the remaining gas must be nitrogen, for all the hydrogen must have been converted into water by the oxygen of the oxide of copper. The results obtained by this method agree with theory to the second, and often to the third decimal place.

On the Compound or Radical called Kakodyl. By Professor Bunsen, *of Marburg.*

The object of this paper was to describe a new radical resembling alcohol, in which arsenic replaced the oxygen of that compound. This radical enters into numerous combinations, forming, with oxygen, a peculiar acid, called kakodylic acid. The oxide of kakodyl has so great an affinity for oxygen, that when exposed to the air it immediately inflames. The bodies produced by the combustion are arsenious acid, carbonic acid, and water. By the further oxidation of the oxide of kakodyl, kakodylic acid is produced. The sulphuret of kakodyl is similar in composition to the oxide, and participates in many of its properties. The telluret, selenuret, iodide and bromide of kakodyl

were also examined. The danger attending these experiments is very great, and the poisonous effects produced by the inhalation of the vapour were described as dreadful. Kakodyl is produced from the liquor of cadet, and is extremely interesting as being a link connecting organic and inorganic chemistry. Professor Bunsen is engaged in further experiments on this subject, and has already obtained many new combinations.

On the Identity of Spiroilous and Saliculous Acid. By Dr. ETTLING.

The oil discovered by M. Pagenstecher, and obtained by the distillation of the *Spiræa Ulmaria*, has already attracted considerable attention. Dr. Ettling had analysed it previously to the appearance of M. Piria's valuable paper on Salicyl. The oil decomposes into two oils on keeping, one of which is specifically lighter, the other heavier than water. Dr. Ettling discovered that the latter possessed the same composition as hydrated benzoic acid. The action of ammonia on the oil gives rise to some new interesting compounds. In order to obtain these compounds it is indifferent whether saliculous or spiroilous acid be employed. The final product of the action of ammonia upon these is the amide of salicyl (salicylamide). This body evidently belongs to the class of amides, for it does not evolve ammonia, on the addition either of potash or of acids. The cause of its formation is as follows: three atoms of saliculous acid unite with three atoms of ammonia, and form saliculite of ammonia, whilst three of hydrogen and oxygen combine together and form water. This salicylamide unites with copper, iron, and lead, forming compounds.

On a New Method of Preparing Morphia and its Salts. By Dr. MOHR, *of Coblentz.*

The plan adopted by the author for separating morphia from narcotin and all other heterogeneous substances, consists in dissolving it in an excess of caustic lime, and precipitating it by muriate of ammonia. This method of precipitation is, in principle, very similar to the precipitation of alumina from a solution of caustic potash. The process is as follows:—The opium is boiled in water, in which it readily dissolves; the decoction is strained through a linen cloth, and the dregs are pressed; this operation of boiling and straining is repeated twice on the same quantity of opium, and the solution of the whole concentrated until its weight is four times that of the opium employed. The concentrated solution is, while still warm, mixed with milk of lime, prepared with a quantity of dry lime equal to the fourth part of the weight of the opium. The mixture is heated till it boils, and is filtered through linen while hot. The filtered liquor has a light brown yellow colour. While still hot it is mixed with pulverized sal-ammoniac in excess; the lime is saturated with muriatic acid, ammonia is set free, and the morphia is precipitated. When the solution is greatly concen-

trated the precipitation is instantaneous, and is almost equal in volume to half the solution. When, however, the solution is less concentrated, there is at first no precipitation, but as the liquor cools, needles appear, and at a certain point a large mass of precipitate is suddenly formed. The peculiarity of this process is, that it affords a well crystallized and fine product of morphia, without requiring the use of alcohol. This is owing to the circumstance that the ammonia is not added in a free state, but is generated in immediate contact with the substance to be acted upon. The morphia is nearly colourless: by dissolving it in muriatic acid, and subjecting the solution to crystallization, we obtain muriate of morphia in perfectly white crystals quite pure. The milk of lime, it is to be observed, must not be added to a boiling hot solution of the crude opium, otherwise the precipitate adheres to the sides of the vessel, and does not afterwards re-dissolve perfectly. The liquor containing the morphia should either be cold, or only lukewarm when the milk of lime is added to it. If it is boiling hot, it must be added to the milk of lime, and not *vice versâ*.

On the Action of Nitric Acid on the Chlorates, Iodates, and Bromates of Potassa and Soda. By Professor FRED. PENNY.

The present communication contains the details and results of some experiments undertaken with the view of obtaining additional confirmation of the correctness of the author's researches on equivalent numbers. In this he has been disappointed, as the action is attended by circumstances which render it inapplicable to so delicate a purpose as the determination of equivalent numbers. The results, however, that he has obtained are new, and he considered them of sufficient interest to be worthy the attention of the Section. In order to examine the action of nitric acid upon chlorate of potassa, a known weight of the salt was mixed in a retort with a measured quantity of the acid, and the mixture heated on a sand-bath; as soon as it became warm, chlorine and oxygen were evolved in a state of mixture and not of combination, and the chlorate slowly disappeared. The solution was then evaporated to dryness, and the saline residue was found to be a mixture of hyperchlorate and nitrate of potassa, in the proportion of three equivalents of the latter to one of the former. The author expresses the reaction that takes place as follows:—

$$4(K + Cl + O_6) \text{ and } 3(N + O_5) = (K + Cl + O_8) \text{ and } 3(K + N + O_6) \text{ and } Cl_3 \text{ and } O_{13}.$$

The action of nitric acid on chlorate of potassa differs, then, from the action of sulphuric acid on the same salt. With nitric acid the salt is decomposed tranquilly, and the chlorine and oxygen are liberated uncombined; whereas with sulphuric acid these gases are evolved in a state of combination, forming that dangerous explosive compound, chlorous acid. Nitric acid is therefore to be preferred for the preparation of hyperchlorate of potassa, as with it the operation may be conducted without those violent detonations that are so apt to occur with sulphuric acid. The action of nitric acid on chlorate of soda is the

same as upon chlorate of potassa. The chlorine and oxygen set free are in a state of mixture, and every 4 atoms of chlorate yield 3 of nitrate and 1 of hyperchlorate. The hyperchlorate of soda is a very soluble salt, and crystallizes in small rhombs. It is readily decomposed by heat, but is unacted upon by hydrochloric acid. It deliquesces by exposure to the air. The action of nitric acid on an iodate is very different from that on a chlorate, and is well illustrated in the case of iodate of potassa. When iodate of potassa is boiled for some time with a large excess of nitric acid, it is decomposed into potassa and iodic acid; the potassa combines with its proportionate quantity of nitric acid, forming the nitrate, and the iodic acid is deposited from the solution in minute, hard, and transparent crystals. If the acid solution of nitre, containing the iodic acid, be then evaporated, a reaction takes place; the iodic acid decomposes half of the nitre, sets free its nitric acid, and combines with the potassa, forming the biniodate. This change is completed when the mixture is dry, and if the heat be then withdrawn a definite mixture of biniodate and nitrate is obtained. If the heat be continued, a still further change occurs, the iodic acid expels the whole of the nitric acid, which is evolved as nitrous acid, and oxygen and neutral iodate of potassa remain. By adding a fresh portion of nitric acid to this iodate, the same changes may be produced by a proper regulation of the temperature. By acting upon iodate of soda with nitric acid, Prof. Penny has obtained a biniodate of soda, and by adding a considerable excess of iodic acid to a solution of iodate of soda he has found a teriodate of soda. Both of these salts are anhydrous. The biniodate of potassa contains 1 atom of water. He also finds that crystals of iodate of soda contain different quantities of water, according to the strength of the solution from which they have deposited. From a hot and strong solution this salt crystallizes in acicular tufts, and these crystals contain 2 atoms of water. If the solution be rather weak, long four-sided prisms are obtained, and these contain 6 atoms of water. If a solution of iodate of soda be evaporated spontaneously, large irregular prisms deposit, and these contain 10 atoms of water. They effloresce rapidly by exposure to the air, and lose in this way 8 atoms of water. The action of nitric acid upon bromate of potassa was next examined, and was found to differ remarkably from the actions of this acid on the chlorate and iodate. Neither hyperbromate nor bibromate is produced, but merely nitrate of potassa. The nitric acid sets free the whole of the bromic acid, and this, at the moment of its liberation, is resolved into its elements, bromine and oxygen. In conclusion, the author remarks that the action of nitric acid on these three classes of salts affords a ready method of distinguishing them from one another.

On a New Salt obtained from Iodine and Caustic Soda. By Professor FRED. PENNY.

While examining the action of iodine on carbonate of soda a salt was obtained, which crystallized in regular six-sided prisms, and which

gave by analysis sodium, iodine and oxygen, in proportions not corresponding to any known compound of these elements. The same salt was also prepared by saturating a solution of caustic soda with iodine, and allowing the solution to evaporate spontaneously. At first this salt was thought to be the same as that described by Mitscherlich in his Elements of Chemistry, and to which he gives the following composition, $Na\,I + Na\,O, I\,O_5 + H\,O_{20}$; but the analysis gave very different results. Professor Penny gives the following characters of this salt. It is white and inodorous, has a sharp saline taste, crystallizes in short six-sided prisms, is soluble in cold and hot water, and is decomposed by alcohol into iodate of soda and iodide of sodium. It effloresces by exposure to the air, and is very readily decomposed by heat; water in abundance is first evolved, and then oxygen with a trace of iodine. Its solution is perfectly neutral to test papers, gives a pale lemon-yellow precipitate with acetate of lead, yellowish white with nitrate of silver, and a fine bright yellow with pernitrate of mercury. It is not affected by solution of starch, but instantly decomposed with the precipitation of iodine by nitric, sulphuric, acetic and hydrochloric acids. The latter acid in excess converts it wholly into chloride of potassium. He detailed a remarkable circumstance attending the formation of this salt from iodine and caustic soda. When the solution is evaporated spontaneously, long prismatic crystals of iodate of soda deposit; but as the evaporation continues these crystals are re-dissolved, and are replaced by those of the new salt. In one experiment this change was very striking. The solution on Saturday night had deposited an abundance of fine crystals of iodate of soda; but on Monday all these had disappeared, and a crop of the new salt had crystallized. The prior deposition of iodate of soda generally occurs in the preparation of this salt; and from other experiments of the author it seems necessary that there should be excess of iodide of sodium present in the solution, and that the solution should be strong in order that the salt may form. When this salt is dissolved in water, and the solution evaporated spontaneously, crystals of iodate of soda deposit, but very few of the new salt will form. The salt may also be procured by pouring a saturating solution of iodide of sodium on crystals of iodate of soda, and setting them aside for some days. The crystals will be dissolved, and be replaced by crystals of the new salt. Professor Penny then gave the details of his analysis of this salt, and the following formula as agreeing best with his result: $Na_5\,I_5\,O_{12} + 38\,H\,O$; or regarding it as a compound of iodate and iodide, it may be thus represented: $3\,Na\,I + 2\,Na\,I\,O_6 + 38\,H\,O$. According to this view it is the sesqui-iodide of iodate of soda.

Additional Observations on the Voltaic Decomposition of Alcohol. By ARTHUR CONNEL, *Esq.*

The author showed, a few years ago, that under powerful voltaic agency, the water entering into the constitution of absolute alcohol was resolved into its elements, hydrogen being evolved at the negative pole, and

oxygen going to the positive, where it produces secondary effects of oxidation*; and that the galvanic agency was greatly increased by dissolving minute quantities of potash in the alcohol, so small a quantity as $\frac{1}{10000}$th part having a marked effect, by increasing the conducting power of the liquid. As it had been objected that the water of the hydrate of potash employed might contribute to the result, the author has since employed potassium instead of hydrate of potash, with precisely the same effects. It is known, that when potassium is dissolved by alcohol, it is oxidated with evolution of hydrogen, so that in this way we produce the same consequences as if we added anhydrous potash. By adding small quantities of potassium, such as $\frac{1}{100}$ or $\frac{1}{500}$, to absolute alcohol (sp. gr. ·7918, at 66° F.), and then submitting the liquid to voltaic action, hydrogen was given off at the negative pole; and when the effect ceased, it was renewed by re-charging the battery, and again adding a similar small quantity of potassium; and the usual secondary effects of oxidation were produced at the positive pole. In instituting a comparison between the quantity of hydrogen thus given off, and that evolved by the same electric current from acidulated water, it is necessary that a powerful current should be employed, and a somewhat larger quantity of potassium dissolved; because otherwise, from the inferior conducting power of the liquid, and from a little of the hydrogen entering into the constitution of the secondary products, the quantity of hydrogen evolved from the alcohol is somewhat less than that from the acidulated water; and the comparison is best instituted during the early stages of the action, because the conducting power of the liquid diminishes as the potash gets saturated by the secondary products, and the electric energy declines also. The author still regards these experiments as affording the only *direct* proof which we yet have of the existence of water, as such, in absolute alcohol.

On Resins. By Professor JOHNSTON.

In this paper the author drew attention to the following facts, apparently established by a table of analytical results, which he exhibited, and has had printed. 1st. That the resins differ from each other in the quantity of oxygen they contain. 2nd. That in those in which the atoms of oxygen are the same, the hydrogen may vary, and that this is another cause of difference in the properties of the resins. 3rd. That in all the resins hitherto carefully analysed, the number of atoms of carbon is constant. 4th. That the resins, as a natural family, may be represented by a general formula containing two variables. 5th. That the known resins divide themselves into two groups, possessing unlike chemical and physical properties; that of one of these groups colophony may be considered as the type, and that it is represented by $C_{40}\,H_{32} \pm {}_x\,O_y$; that gamboge, or dragon's blood, may be considered as the type of the other group, which is represented by $C_{40}\,H_{24} \pm {}_x\,O_y$.

* Transactions of the Royal Society of Edinburgh, vol. xiii.

On the Resin of Sarcocolla. By Professor JOHNSTON.

The resin of sarcocolla of commerce is separated, by water, into three portions.

1. A gum A, which does not dissolve in water or alcohol, but which is in a great measure washed out by means of the former solvent.

2. A portion B, insoluble in water, but soluble in alcohol, which is of a resinous aspect, and is represented by $C_{40}\ H_{32}\ O_{14}$.

The hydrate is $C_{40}\ H_{32}\ O_{14} + 2\ HO$ when dried at 60°.

This portion B is separated (decomposed?) by bases into two or more organic compounds, the alcoholic solution giving, with neutral acetate of lead, a salt containing an organic constituent represented by $C_{40}\ H_{25}\ O_{16}$.

Ammonia throws down from the mixed solutions a second salt of lead, the constitution of which has not yet been determined.

3. The portion taken up by water from the crude sarcocolla when evaporated to dryness, is separated by alcohol or æther into a soluble (C), and an insoluble portion D.

4. The soluble C, dried at 212°, gives discordant results, approaching to $C_{40}\ H_{32}\ O_{15}$, but when treated with bases, gives salts containing organic constituents of a different constitution.

A neutral acetate of lead throws down a salt represented by $Pb\ O + C_{40}\ H_{28}\ O_{15}$; and the subsequent addition of the neutral *trio* acetate, a salt represented by $2\ Pb\ O + C_{40}\ H_{32}\ O_{16}$.

5. The portion D, insoluble in alcohol, but soluble in water, consists of a gum, and of a substance which is precipitated by neutral acetate of lead in curdy flocks.

The investigation is still in progress, and the results are to be considered as open to correction.

On some Varieties of Peat. By Professor JOHNSTON.

The author exhibited some varieties of peat from the Moss near Paisley, which he stated were illustrative of a transition from the comparatively fresh vegetable matter to a substance resembling coal, but which he affirmed to be ulmic acid. The author stated that the same substance might be obtained from peat by digesting it in ammonia, and afterwards precipitating the brown solution by an acid; while on the other hand, caustic potash extracts another, and which he proposed to term *humic acid.*

On a Mode of Detecting Minute Portions of Arsenic. By Dr. CLARK, *of Marischal College, Aberdeen.*

This mode has been applied by the author to the detection of arsenic in commercial specimens of the metals, tin and zinc. Grain tin, made in Cornwall, contains arsenic, which seems to be the occasion of the peculiar smell of the hydrogen evolved from that metal by the action

of acids. All the specimens of commercial zinc that the author had happened to try, were found to contain arsenic.

Pure muriatic acid, diluted with distilled acid, is poured upon the metal, and the hydrogen evolved is passed first through a solution of nitrate of lead, and next through a solution of nitrate of silver. Nitrate of lead seems not acted upon by arseniuretted hydrogen, at least when in very small proportion; but were any sulphur present in the metal, hydrosulphuretted hydrogen would be evolved in consequence, and the solution of nitrate of lead would be blackened, which, however, the author did not observe ever to occur. But nitrate of silver seems immediately to be acted upon by most minute portions of arseniuretted hydrogen. A bluish-black precipitate is formed, which, to judge from a qualitative analysis, appears to be an arseniuret of silver. This bluish-black precipitate may be collected with remarkable facility, from its falling readily from the solution, which it leaves perfectly clear. Heated in a small tube, so that the matter heated comes into contact with the air, the bluish-black precipitate evolves arsenious acid, which, by the liquid tests, may be further satisfactorily recognized. Antimony produces a similar precipitate, so that the mere appearance of the precipitate is not enough, without the production and recognition, by the usual methods, of the arsenious acid.

By a few evident modifications, this method may be applied to medico-legal investigations.

On the Tests for Sulphuric Acid when thrown on the Person. By R. D. Thomson, *M.D.*

The object of the author was to discuss the accuracy of the modes of testing sulphuric acid when employed for criminal purposes, and especially when thrown on the person. A case had lately occurred to him in practice, and which was brought before the last session of the Central Criminal Court, which proved that the mode of determining the presence of *free* acid by *mere* testing was by no means satisfactory. A woman, in a fit of rage, threw a quantity of oil of vitriol at the face of a cabmaster in the neighbourhood of Euston-square, and before the unfortunate sufferer could wash off the acid only two minutes had expired; yet the consequence was loss of vision in the eye. The author stated, that having attentively considered this case, and made a series of experiments on the eyes of dead animals, he had discovered that this kind of blindness was perfectly curable; and he had accordingly proposed an operation for this purpose in a paper read at the Medical Section. But, besides having his face injured, the hat of the man was discoloured also with the acid. This article of dress was sent to the author, to determine the nature of the agent in this work of destruction. The result of his experiments was, that both the injured and entire hat contained sulphuric acid, as tested by nitrate of barytes; and a solution of the soluble matter of both states of this article of dress, afforded an acid reaction. It was therefore necessary to adopt

some method which would afford a discriminating test between the free and combined acid. The usual mode, viz. by boiling with carbonate of lead, and concluding, if any insoluble sulphate of lead was formed, that the acid existed in a free state, was found to be totally fallacious, because carbonate of lead decomposes sulphate of soda, contrary to the opinion stated in works of medical jurisprudence. Besides, it was shown that many of the usually so-called neutral sulphates exhibit in reality an acid reaction upon test-paper, as in the instances generally of sulphates of potash, iron, soda, barytes, and also in the case of alum, &c.; and hence the excess of acid attached to these salts, would be apt to act as free acid upon the barytes test. The author, therefore, concludes that the only demonstrative proof which chemistry affords, is a quantitative analysis. Thus he found the entire hat to contain ·356 per cent. of sulphuric acid, probably in the state of alum or copperas, and the injured hat, 1·379 per cent., or in other words, the hat had received by the injury 1·023 per cent. of free sulphuric acid. Here then was afforded clear evidence of the nature of the agent employed to effect the injurious object, which could not have been conclusive if the matter examined had only amounted to a drop or stain.

The author directed attention to a point connected with sulphuric acid in a medico-legal point of view, viz. that the oil of vitriol of commerce always contains in this country nitric acid, in addition to various other impurities. Barruel has stated that sulphuric acid is capable of dissolving platinum. The author has not been able to satisfy himself that it dissolves any sensible quantity of gold leaf. Barruel attributes the property which he states it to possess, of dissolving platinum, to the sulphuric acid, assuming the function of muriatic acid. But the author is not aware of any experiment which would authorize this conclusion. He is rather inclined to attribute the action, if such an occurrence takes place, to the muriatic acid which is present in all the oil of vitriol prepared from sulphur that he has examined. It is given out in sensible quantities, when a solid oil, such as cocoa-nut oil, is acted on by sulphuric acid. This he ascertained several years ago, when examining some Indian oils; and Dr. Kane has since corroborated the fact of the existence of muriatic acid in oil of vitriol. Although the author has not been able to observe the solution of any sensible quantity of gold leaf by the action of oil of vitriol, *per se*, yet if a few drops of muriatic acid be added, the action becomes very powerful; and by the administration of heat, platinum also is dissolved. These facts, therefore, prove that wherever we have oil of vitriol, we may expect also nitric acid. The author added that he knew of no certain mode of detecting the presence of nitric acid, save by the property which it possessed of dissolving gold and platinum, on the addition of muriatic acid. Pure morphia has no action upon nitric acid; it is the resin which generally accompanies that alkaloid which produces the characteristic yellow colour. But the author found that preparations of opium, in which the resin was excluded, afforded no colour when nitric acid was added. From an examination

of numerous cases of poisoning by opium, which had appeared before the Middlesex coroners, he had come to the conclusion that the resin of opium test for nitric acid afforded only an auxiliary method of arriving at the truth, as its characters were frequently verified by other organic substances.

On Bleaching Vegetable Wax. By Mr. E. Solly.

In the course of the summer the author made a series of experiments on the best method of bleaching vegetable wax, the green colour of which is very difficult of destruction, and of course a considerable objection to its use in the manufacture of candles. On trying most of the methods usually described as being fitted for the purpose, he found them all more or less objectionable, or inapplicable on a large scale. Some were tedious, requiring a long time for their completion, others expensive, whilst others again were inconvenient, from the difficulty with which the residuum of the materials employed in bleaching were separable from the bleached wax. The author found that the best effect was produced by chlorine; but in this case it was necessary that the materials used to evolve the gas should be intimately mixed with wax, and then of course the difficulty of separating the residue occurred, and when a stream of chlorine was slowly passed through the wax, the process was very slow and tedious. He subsequently found that strong nitric acid was a very powerful decolorising agent, and it possessed the advantage of leaving no residue which was at all difficult of separation; the expense of this process was, however, a great objection to its use. The following method was ultimately employed. The wax was melted, a small quantity of sulphuric acid was poured in, composed of one part of oil of vitriol to two of water, and then a few crystals of nitrate of soda were stirred in; the whole was then agitated with a wooden stirrer, and kept heated. Nitric acid was thus evolved in considerable quantity and purity from a large surface, and in such a manner that all the acid evolved must necessarily pass through the melted wax. This method answered the purpose very completely; the process was cheap and rapid, and the residuum being merely a little solution of sulphate of soda was very easily removed. When it is desired to employ chlorine in place of nitric acid as the bleaching agent, the same process may be adopted.

On a peculiar Class of Voltaic Phænomena. By Mr. Sturgeon.

The author directed attention to some experiments published by himself in 1830, and to his theory respecting the electro-chemical action of the simplest metals on acid and other solutions. He stated that the fact of iron not precipitating copper from its sulphate and other solutions, as recently observed by Professor Schönbein, was one of the many beautiful phænomena discovered by Keir, and published in the Philosophical Transactions for 1790.

Experiments on Carbonic Acid thrown off from the Lungs. By Mr. M'Gregor.

These experiments, performed by the author while resident in the Royal Infirmary of Glasgow, were instituted with a view to ascertain whether the quantity of carbonic acid thrown off from the lungs differed in health and disease. The mean per cent. in health he found to be 3·5 per cent., a quantity which very nearly corresponds with that assigned by Dr. Thomson of Glasgow, and Dr. Apjohn of Dublin; that found by the former being 3·72 as a mean ultimate result, while that of the latter was 3·6. In the eruptive stages of small-pox, measles and scarlet fever, the amount of carbonic acid evolved from the lungs was considerably increased, in the former to from 6 to 8 per cent., and in the two latter to from 4 to 5 per cent. During the aggress and climax of these diseases, the per centage of carbonic acid showed the above increase, while in proportion as convalescence established itself, and the skin re-assumed its normal appearance, the per centage of carbonic acid gradually diminished. Ten cases of each of the above specified diseases were so examined. In chronic skin-disease an augmentation was also observed, and in one case of ichthyosis the mean per centage amounted to 7·2 per cent. The scaliness in that case was universal, and ultimately proved fatal. In diabetes mellitus, a disease in which the aliment is converted into sugar, and eliminated in the form of urea and sugar, no normal aberration could be detected; the carbon in that case being eliminated in the form of sugar and urea.

Description of a New Instrument for Measuring the Refractive Power of Minute Bodies. By Alexander Bryson, *of Edinburgh.*

While engaged in a series of experiments on the polarising properties of minute crystals, I found that when the microscope was focused to the second surface of a plate of glass, on which some minute crystals of Greenockite were placed, the addition of a thin film of Canada balsam spread on the slip of glass, prevented entirely the appearance of the Greenockite, until the body of the microscope was raised two hundredths of an inch above its former position.

This property of bodies, with parallel planes, affords a means of ascertaining the approximate refractive power of minute bodies. On this principle Mr. Bryson has constructed an extremely simple microscope. On its stage is placed a piece of crown-glass, the refractive power of which has been ascertained, having a few fine lines drawn upon its surface with a diamond point. If a piece of topaz of $\frac{1}{10}$th of an inch in thickness is now placed above the lines, it will be found necessary to raise the body of the microscope ·045 of an inch higher than it was while viewing the lines before they can be observed after the interposition of the topaz. This difference of focal length then becomes an index to the difference of refractive power between the glass plate and the crystal of topaz. All that we require is to procure the means of ascertaining

minute differences of focal length, which is easily accomplished by a scale and vernier, reading to the thousandths of an inch.

Thirteen minerals were cut with parallel planes, all exactly $\frac{1}{10}$th of an inch thick; they were placed on the glass micrometer, focused in every experiment at ·210 upon the scale; the difference of focus is therefore the remainder of ·210 subtracted from the figures opposite the name of each mineral in the annexed list.

Greenockite, Bishopton, Clyde	·275
Garnet, Ceylon	·260
Amethyst, Oriental	·258
Prehnite, Bishopton	·258
Topaz, New Holland	·255
Quartz	·255
Sulphate of baryta	·255
Beryl, planes perpendicular to axis	·255
Opal, common	·245
Rose quartz	·246
Amethyst, Brazil	·245
Fluor spar	·243
Arragonite	·235

On a New Method of Crystallographic Notation. *By Mr.* J. J. GRIFFIN.

The author classes the planes of crystals into seven elementary sets, which he calls "Forms." The planes of crystallized minerals consist of these forms in various states of combination. Hence a natural crystal, speaking crystallographically, is a "Combination." The seven fundamental forms are named P, M, T, MT, PM, PT, PMT. These symbols show the relations of the planes which constitute the Forms, to what are termed the axes of a crystal. These axes are three mathematical lines which cross one another in the centre of the crystal, at an angle of 90°. The position of the first of these axes is perpendicular, whence it is called the principal or perpendicular axis, and is denoted by the sign p^a. The second axis is called the minor or middle axis, and is denoted by the sign m^a. It passes from the front to the back of the crystal. The third axis is the transverse axis. It passes from the left to the right side of the crystal, and is denoted by the sign t^a. All the planes of a crystal, when extended, cut one or two or three of these axes, and they are denoted by letters referring to the axes which they cut. Thus P means two planes that cut p^a; M, two planes that cut m^a; T, two planes that cut t^a; MT, four planes that cut m^a and t^a; PM, four planes that cut p^a and m^a; PT, four planes that cut p^a and t^a; PMT, eight planes that cut all the three axes. When the axes are cut at different distances from the centre of the crystal, the lengths of the respective axes are indicated by indices placed between the letters, which constitute the symbol of the form. Thus, $M\frac{1}{2}T$ denotes a vertical rhombic prism, the diagonals of whose cross section are as the numbers 1 and 2. And $P\frac{5}{2}M\frac{1}{2}T$ denotes a

rhombic octahedron, whose three axes have the relation of p^a_3 m^a_1 t^a_2. Mr. Griffin entered into various details to prove that the occurrence of planes, not representable by one or other of these seven forms, was a mathematical impossibility, and that the proposed system of notation was amply sufficient for all the purposes of the chemist and mineralogist, while it had over other systems of crystallography the advantage of requiring but a small amount of mathematical knowledge.

Prof. Jacobi made some observations respecting his discovery of Galvanoplastics, or electrotype, from which, and from printed documents, it appeared that he had communicated a notice of the discovery to the Petersburgh Academy on the 5th of October, 1838. In his pamphlet, 'Die Galvanoplastik,' the date of this communication is 5th of October, 1839; but it was stated that this was a typographical error. The first published account of the discovery appeared, according to Prof. Jacobi, in a Petersburgh journal of the 30th October, 1838*.

GEOLOGY.

On the Coal Formation of the West of Scotland. By Mr. J. Craig.

Mr. Craig had surveyed this district at the suggestion of the Local Committee of the British Association in Glasgow. After describing the general features of the district, and the character of the superficial deposits, and mentioning that he had found the *Mytilus edulis*, the *Littorina littoralis*, and other recent sea-shells at the elevation of 360, 100, 80, and 40 feet above the present level of the sea, Mr. Craig proceeded to describe the different portions of the strata, as subdivided and coloured in the Map and Sections. These he classed as follows:—

1st. The upper red sandstone series.
2nd. The upper or fresh-water coal series.
3rd. The upper marine or limestone series.
4th. The lower coal series.
5th. The lower marine limestone series.
6th. The old red sandstone.

1st. The upper red sandstone, consisting of red and variegated sandstones, shales, some thin seams of coal, and a very few traces of coal plants, extends over very considerable portions of the regular coal beds both in Lanarkshire and Ayrshire. On the south of the deposit in Lanarkshire, it appears not to be conformable with the upper coal series as on the north, but occurs in actual contact with some of the

* *Der St. Petersburger deutschen Zeituug.*

lowest members of the lower coal series at Crossbasket. It is not traversed in Lanarkshire as in Ayrshire by trapdykes.

2nd. The upper or fresh-water coal series contains about thirty seams of coal, seven or eight of which are workable. The first workable coal lies generally about forty-five or fifty fathoms below the red sandstone; but at Rosehall the red colour prevails as low in the series as the third workable coal. The first or upper coal seam is from $2\frac{1}{2}$ to 3 feet thick in the parishes of Old and New Monkland; but in those of Dalziel, Dalserf, and Hamilton, it sometimes measures from six to ten feet. When so thick, it is probably a junction of the first and second seams. The second and third coal, when separate, average each about four feet; when united, as is sometimes the case, they form eight or nine feet of coal. The fourth coal is generally too thin to be workable; but in the neighbourhood of Glasgow it measures $2\frac{1}{2}$ feet. The fifth or splint coal measures from $2\frac{1}{2}$ to 6 feet thick. The coals that underlie the splint are not so regular, either as to thickness or geographical distribution. There are three seams workable in the Monklands—the first is $2\frac{1}{2}$ feet, the next four feet, and the lowest two feet thick. Below these, in the parish of Shotts, there is a cannel coal. The distance from the first or ell coal, to the fifth or splint coal, is about thirty fathoms. The area in which these valuable beds of coal occur, extends in Lanarkshire from Glasgow to Carluke, a distance of twenty miles. In breadth it varies from six to fifteen miles: fifteen to twenty square miles of this area is occupied by the upper red sandstone.

The fossil shells found in this formation are all of fresh-water origin. There are from seven to ten varieties of the genus *Unio*. The different species are characteristic of different portions of the stratification, the larger species being lowest and the smaller highest in the series. The remains of the *Megalichthys Hibbertii* prevail from the lowest coal to the upper black-band ironstone. This is also the case with the *Gyracanthus formosus* of Agassiz. The *Ctenacanthus* and two other species not yet described, are also found in the upper ironstone, and in the roof of the splint coal. These and other ichthyological remains are found in great abundance in the roof of the Shott's coal, which is the second seam below the splint coal. The shales of this series abound in fossil ferns, Stigmaria, Lepidodendra, Asterophyllites, Sigillaria, and other coal plants.

The *Sternbergia approximata* has been found in the roof of the splint coal. It is worthy of remark, that the *Stigmaria ficoides* is very frequently found in the shales, with the leaves attached to the stem and spread out laterally, in a manner which never could have occurred had the plant been drifted from a distance. The ripple-marks which are observable on almost all the shales and laminated sandstones, not only in the upper series, but through the whole of the carboniferous formation, tend also to show that these portions of the coal strata, at least, were deposited in shallow water. Fossil trees in a vertical situation are rare. Mr. Craig had only seen them in three places,—that at Balgray Quarry, near Glasgow, is the most remarkable, as there were

many stems seen in the stone, with their roots ramified through it, and the stems quite vertical; circumstances which clearly indicate that they grew in their present position. Mr. Craig then described the different carboniferous black band ironstones found in the upper coal formation. These he classed as the upper, which is about fourteen inches thick, and lies 24 fathoms above the first, or ell coal. It is only wrought in the parish of Old Monkland, at a place called Carnbroe. The middle or Airdrie black band lies about sixteen fathoms below the splint coal, and measures from fourteen to twenty-two inches thick; the lowest lies much lower in the stratification, and is of about the same quality and thickness as the Airdrie black band.

3rd. Below the coals and ironstones already noticed, we arrive at a marine series, containing three or four limestones, which, with their associated shales, contain—Encrinites, Bellerophons, Nucula, Euomphali, Orthoceratites, and other remains decidedly marine. This portion of the strata contains only two or three very thin seams of coal; it is about 200 yards thick. This group is denominated the upper limestone series.

4th. We now arrive at the lower coal series, which contains no limestones, but a number of coals, the lowest of which is the cannel coal, measuring from two to three feet thick. The main coal lies fifteen fathoms above the cannel coal. These and some other thin seams are associated in some localities with valuable black band ironstones. These are wrought at Keppoch, near Glasgow. The upper ironstone measures from fifteen to sixteen inches. The under band varies from four to ten inches in thickness.

The black band ironstones of the Glasgow coal-field contain very little clay, and about as much carbonaceous matter as serves to calcine it; on which account it is considered more valuable than the clay ironstones hereafter to be noticed.

Below the lower coal series there occur several small groups of clay ironstones imbedded in shale, each separated from the other by beds of sandstone and an occasional stratum of limestone. Mr. Craig showed a vertical section wherein all these beds were exhibited, the ironstones, amounting to sixty-six in number, twenty feet of which might be wrought in different winnings in the same pit.

5th and 6th. Underneath these ironstones, shales, &c. lies the main limestone, measuring from four to six feet thick, beneath which is a layer of aluminous shale, from which alum is manufactured. This bed is followed by a seam of coal from four to five feet thick, of a sulphureous nature, and containing nodules of iron pyrites. These beds are succeeded by limestones, shales, and sandstones, and finally by an extensive formation of thin compact limestones imbedded in shale, and finally by old red sandstone. Such is the general description of the strata developed on the Clyde and its tributaries, from Lanark to the Vale of Leven.

Mr. Craig then entered upon a description of the different coal-fields in Ayrshire. The coal there appears in several basins, among which are those of Irvine, Kilmarnock, Ayr and Dalry. These contain from

four to six or seven workable coals, measuring from $2\frac{1}{2}$ to seven feet thick each, a valuable black band ironstone, and a great many clay ironstones, the whole based upon marine limestones of great thickness.

Mr. Craig's paper was illustrated by large coloured maps, and by sections of the various coal-pits and borings which had been made through the extensive district, amounting to 3600 square miles, which he had surveyed. These were taken at various points in the stratification, and developed the whole in depth to the extent of above 1000 yards.

Notes taken during the Surveys for the Construction of the Geological Model Maps and Sections of the Island of Arran. By A. C. Ramsay.

The interior of the northern and more mountainous district of Arran is a mass of granite, against which recline various stratified formations, ranging between the primary schist and slates, and the new red sandstone. Immediately resting on the central mass of granite lie the schistose and slaty rocks, which are sometimes much contorted, and contain innumerable quartz veins minutely laminated and parallel to the plane of stratification, and in other instances penetrating the slate laterally, being sometimes two feet in thickness. On the slate repose the old red sandstone and conglomerate, containing pebbles of schist and slate quartz, &c. The fragments of quartz are of two kinds,—1st, well-rolled and polished pebbles, probably originating in some ancient mass of quartz now totally destroyed; 2nd, broken and angular fragments, which seem to have been imbedded in the conglomerate immediately after they were detached from the original mass. These last probably proceeded from the larger quartz veins already alluded to, the softer materials in which they occur forming part of the cement which binds the conglomerate together. The anticlinal line is in the centre of the old red sandstone at North Sannox, and at either extremity the coal measures dip to the north and south, being again succeeded by what is generally believed to be the new red sandstone. The southern district of the island is composed of irrupted masses of traps, porphyries, and syenites overlying the stratified sandstone formations. In general it is only where the action of the streams has worn away the superincumbent igneous rocks that this sandstone is visible in the valleys; and in many of the deep gulleys dykes may be seen penetrating, and thence overflowing, the strata to a great depth. In such cases the trap usually assumes a semi-columnar form.

Mr. Ramsay then proceeded to notice some of the phænomena which preceded and attended the elevation of Arran.

The deposition of the various formations has generally taken place under a gradual change of circumstances. Thus, in North Sannox Water, we have first, slate; next, a slaty conglomerate, or pebbles of slate inclosed in slate; then the common pudding-stone; again the slaty conglomerate, and so on, alternating several times. At

the north and south boundaries of the old red sandstone, between Fallen Rocks and Corrie, it assumes a conglomerate form; but before passing into the coal measures, we find the same pebbles, of which it is composed, inclosed in lime, forming a carboniferous limestone conglomerate; after which succeed the various sandstones, limes, and shales of the coal formations. It is equally impossible to define the boundaries of the coal measures and the new red sandstone. As, therefore, there is no sudden change from one set of rocks to the other, Mr. R. inferred that they were regularly laid on each other, without any material intervening change having taken place in the bed of the sea where they were deposited.

On the question, through what agencies did these strata attain their present elevation, the author states the following facts:—There are no fragments of granite in any of the overlying formations. Granite often penetrates the slate in veins, but has nowhere overflowed the slate. Probably, before the deposition of the old red sandstone, the melted granite was formed under the slate, partially elevating it above the water and cracking it in many places. Into these fissures the granite infused itself, cooled, and was subsequently upheaved and protruded in its present crystalline form. In proof of this, it is stated—1st, that rounded fragments of slate and schist are imbedded in the old red sandstone; 2nd, that in many places a shallow valley intervenes between the highest point of the slate and the central granite; 3rd, the separated edges of the slate dip towards the granite; 4th, had the sandstone rocks completely overlaid the slate before its first partial elevation, they would have occupied the low ridges which now encircle the granite.

There are in Arran two granites distinct in character, the one coarse and crystalline, the other of a finer and softer texture. The fine granite occupies the centre of the granitic district, the coarse forming the external ridges next the slate. The fine granite also penetrates the coarse variety in veins. Trap and pitchstone dykes penetrate the coarse granite in many places; but as no dykes have yet been found in the fine granite, and as these dykes are always cut off by the fine granite when they approach it in the coarse rock, it would appear that the fine granite is even newer than the trap dykes; and if these last are contemporaneous with the traps and porphyries of the south end of Arran, the fine granite must also be of later origin than they are. In the year 1837, Mr. Ramsay discovered a mass of fine-grained granite to the west of Glen Cloy (called by M. Necker, who noticed it last year, Ploverfield) associated with syenite, and sending veins into the adjacent red sandstone.

With regard to the more recent elevations, the author stated, that an ancient sea cliff, the foot of which is about forty feet above the level of the sea, surrounds great part of the island, and, gradually sloping from this to the modern beach, shells are found similar to what are now found on the shore. These shells are even found at the entrances of the water-worn caves so common in this cliff; and these caves, instead of lying horizontally, dip agreeably to the anticlinal line, their

pillars being at right angles to the plane of stratification, not to the horizontal level, clearly showing that they were elevated into their present position at an epoch subsequent to their formation. Between this cliff also, and the sea, are numerous boulders of granite, which rest not on the broadest and most solid parts, but on their apices, as if the action of the advancing and retiring waves while they were within high water-mark, had washed away the lower portions of the rock and left them in their present position. A regular series of these forms may be observed on the shore, and the further they are removed from ebb-tide, the more do they assume the form of inverted cones.

Another evidence of a still more recent elevation is this, that near the coal on the east coast, is a bed of red limestone; and six or eight feet above the level of the sea the surface is entirely honey-combed with the perforations of a species of Pholas.

With regard to the phænomena of the quartz veins in the slate and schist, Mr. Ramsay said, that in part they appeared to owe their origin to the influence of electric currents; but as, where this occurs, the slate or schist is generally much contorted, it is perhaps probable that these currents have been materially aided in their operations by heat; and the process of separating the particles and arranging them in laminæ, would be much assisted if the slate were so far heated and expanded as to allow its component particles liberty of motion. That it was heated to a great extent, is evident from the fact, that at the distance of a mile and a half from the granite the slate exhibits the most marked contortions; and where in immediate contact with the granite, it has in some instances been partially fused.

During the Commonwealth, when Cromwell's soldiers were in Arran, a number of the refractory natives retired into the woods. To gain access to their retreat it was found necessary to cut down many of the trees. These trees were lately found perfectly fresh under $6\frac{1}{2}$ feet of moss.

On another occasion a number of ancient weapons of war were found under three feet of peat moss. These weapons are supposed to be as old as one of the Danish invasions, a battle between the natives and the Danes having taken place where they were found.

Observations on the Superficial Beds in the Neighbourhood of Glasgow. By JAMES SMITH, *F.G.S.*

The uppermost bed is a sand; the next a brick clay, interlaminated with sand, containing marine shells; and then a bed, called in Scotland "till", and containing boulder stones. These are evidently post-tertiary. Between these and the sandstone are three other beds. Mr. Smith has discovered, in elevations, often forty feet above the present shores, beds of shells, containing about eighty-five per cent. of species now existing. Those of extinct species resemble shells from Canada, and indicate a colder climate at the time the animals existed. In the till, shells are of very rare occurrence, although it sometimes contains large bones. The

bed of brick clay seems to have been frequently subjected both to elevation and subsidence; the latter condition being more difficult to observe, from its being often beyond our view. The brick clay of the neighbourhood of Glasgow appears also to coincide in age with the Carse clay of the east of Scotland, as may be seen in the valley of the Tay, where a singular phænomenon is presented by a bed containing stumps of trees, which is covered by another containing littoral shells. He mentioned, that Dr. Thomson, of Glasgow, had recorded a whin dyke that penetrated the superficial sand of that city, but he was not aware of the sand having been altered by it; also, that in Cumbrae a great wearing away of the sandstone was proved by the dykes, as they were now presented to the observer: allowing a foot in the century for this destruction, it would require many centuries to effect what has been done, which induced Mr. Smith to consider the post-tertiary period to be much longer than is generally supposed.

On the Geology of Castle Hill, Ardrossan. By William Keir.

It is situated at the north-west extremity of the great Scotch coal field. On the north side of Ardrossan quay may be seen the old red sandstone dipping beneath the coal; the pier is built on a trap dyke, and the baths upon another; between them the coal strata run into the sea at angles highly inclined. The Castle Hill is formed by an eruption of trap, chiefly in the condition of claystone and clinkstone, with a vein of green serpentine running through it, without rising to the surface. In cutting for the railway, this vein has been exposed and a portion removed. At first it was dark green, very brittle, and frequently coated with steatite; it then became darker in colour, and more compact, and is now becoming like ordinary greenstone. The claystone of the hill appears to have been fissured by the eruption of the serpentine; the fissures are filled with drift, in which are many fragments that bear such marks of fusion as to resemble scoriæ; they have often a ceiling of stalactite, and a floor of stalactitic conglomerate, formed of water-worn pebbles and recent sea-shells, proving the elevation of the rock, the cavernous part being thirty feet above the present tide-level. A little higher, in a sheltered spot, is a bed of recent shells, *Littorina vulgaris* and *Patella vulgaris*, which have been brought there in storms.

On the Granite Formations of Newabbey, in Galloway. By the Rev. J. M. Fisher, *A.M., of Rose Bank, Dumfries.*

"The parishes of Newabbey, Kirkbean, Colvend, and Kirkgunzeon, lie contiguous, and the chains or ridges pervading these, which are wholly composed of granite, stretch in a direction from S.E. to N.W. The granite, it is true, appears more distinct in the above-mentioned parishes; still it stretches in a sort of ridge across the south of the

Stewarty, as far as the Dee, and even appears on the other side, giving existence to the lofty Cairnsmoor.

"At Criffel, which is a huge rounded mountain, towering above most of the hills in the south of Scotland, so as to be seen at a great distance, we have first, a ridge running from S.E. to N.W., terminating in another pretty lofty hill, called Lowters. Then commencing at Shambellie, a little to the north of Criffel, we have another ridge running nearly parallel with the above, consisting of Auchingray and Glensone hills; and further north still is another ridge, almost parallel in like manner, commencing at Whinnyhill, and including Trostive and Graizend; these terminate in a pretty large sort of loch, called Loch Arthur, where the granite formation terminates also; and we find the next hills, Dalscairth and Mabie, exhibiting a distinct stratification of graywacke or clayslate. At the foot of Craigurd, the most northerly of the above ridges affords little interesting. In a sort of morass, interspersed with several large blocks of granite, as if they had rolled down from the ridge above, is one large block, called the *Rocking-stone.*

"Glensone Hill runs nearly S.E., and on the west side, around the brow of the hill, is an extensive ridge of granite rocks, in a curved form, quite bare and rugged; many of the masses very large, disjoined from the body of the hill, and presenting some of them a distinct columnar formation. This is the more remarkable, as the dip of the rock in this hill, and indeed in all the ridges, is westward, at 60° to 70°. To the west of Glensone lies Lowters, the highest of all except Criffel. The east side, fronting Glensone, is steep and rugged; the rocks cropping out quite precipitously, apparently corresponding with the west side of Glensone, though the valley between may extend to the width of 600 or 800 yards, through which Loch Arthur discharges a small stream, which flows into the Nith. On the other hand, the west side of the hill, following the nature of the dip, slopes with a gentle declivity, and is cultivated a considerable way up. This same circumstance is observable at Auchingray Hill, the S.E. side of which is steep and precipitous, the rocks cropping out quite bare; whereas the west side slopes, according to the dip, and is cultivated almost to the top. All these hills and ridges, besides having innumerable blocks of granite scattered over their surface, in ample profusion, and in all directions, seem entirely composed of this rock to a great depth; at least as far as any person has penetrated.

"The highest ridge of the whole remains to be described; that is a hill called Knockandach, i. e. the 'Hill of Drink,' running in a direction nearly north and south, rising to the height of 1200 feet, and which is continued till it finally terminates in the gigantic Criffel. Criffel is certainly an immense mass of granite, changing into syenite in some parts. As on the east side, the rocks crop out in several places, still exhibiting the dip mentioned. Criffel has one principal summit, with three knees or shoulders, one east, one south, and another west; and Knockandach, formerly mentioned, completes the formation northward. On the principal summit has been erected, at different times, and by different contributors, a large cairn of granite rocks, from which the view is most extensive and splendid."

On Earthquakes in Scotland. By D. MILNE, *F.R.S.E.*

Since the year 1788, shocks have been remarked, and have been partially registered. Three-fourths of these seem to have issued from Comrie, in Perthshire, and most of the others from the banks of Loch Ness. The district of Comrie contains mica-slate, clay-slate, and graywacke, with hills of granite and compact felspar, which have elevated the other rocks, the conglomerate of the graywacke containing no pebbles of granite or felspar; but on the former rocks is old red sandstone, containing these pebbles. There are also some remarkable greenstone dykes, which seem to run parallel to each other from sea to sea, in east and west direction, and cutting the oldest and newest strata. The shocks emanated from a granite hill, or from the junction between it and clay-slate, about two miles from Comrie. In October 1839, there were sixty-six shocks; November, twenty-one; December, nineteen; January 1840, eight; February, six; March, thirteen; April, eight; May, five; July, six; the severest being on the 23rd of October, at half-past ten P.M. It was felt as far north as Lochaber and Dingwall, and as far south as Carlisle and Coldstream; varying in intensity in different places. The shocks appear to come from a central point, as their direction is different at different places; at Comrie being from the north, at Dunkeld from the south-west, and at Loch Earn Head from the east. There was an upward motion at Comrie, and at other places it was oblique. There was, likewise, a diminution of intensity and sound as the distance from Comrie increased; and there was, in each place, a marked difference in the damage done to houses. The shock was more severely felt where the soil was alluvial; although, in this case, the sound was not heard, as in rocky places. Occasionally there was a fall of fine black powder, and in some places there was a sensible smell. Various explanations may be given as to the *rationale* of these shocks; but one of the readiest is, the passage of water down to some heated mass below, and its consequent conversion to steam. As bearing on this, the shocks are found to have been more frequent at the time of the year when the greater quantity of rain falls, and when the barometer is lowest. During the last fifty years, 198 shocks took place in the winter half-year, and sixty-one in the summer. At the present time, observations are carefully taken with instruments for the purpose.

D. Milne, Esq., in the absence of Lord Breadalbane, stated the substance of a notice respecting the metalliferous veins of Tyndrum, in which a great variety of metals has been found.

Lord Greenock announced the discovery of lead on the estate of his brother, Colonel Cathcart, on the borders of Galloway and Ayrshire. The vein runs N.N.E. and S.S.W.; it is far distant from granite. It contains five ounces of silver to the ton. There is hematitic iron ore in the vicinity.

On the Sandstone of the Vale of Solway, and the formation of the Closeburn Basin, Nithsdale, Dumfries-shire. By J. A. KNIPE.

The author refers the sandstone to the new red sandstone deposit, remarking that it is a very thin deposit. At Aiket Muir the coal measures are found, and have been penetrated to a depth of 132 feet in search of coal, but without success. At, or at least near Ecclefechan, the true coal measures are seen—on the surface and in the immediate vicinity, *the carboniferous limestone*. Near the limestone quarries at Kelhead a bore has been put down to the depth of 199 feet; this was also unsuccessful in finding coal. The various strata passed through appear to be analogous to the Cannobie pits, and are worked very profitably.

A zone of sandstone extends up the river Annan, from its entrance in the Solway up to Moffat. Another and broader portion of this sandstone extends up the river Nith for several miles north of Dumfries. At the Craigs Quarry are found numerous impressions of the foot-prints of unknown animals. There is a bold escarpment near these quarries formed of alternating beds of sandstone and conglomerate. The section at the Maiden's Bower does not afford so good a specimen as nearer the Craigs House, where the sandstone and conglomerate beds succeed each other to the number of twenty or more. The strata dip at an angle of about 30° to the west, though the dip is very slight at the Maiden's Bower within a mile of these quarries: this is formed by the separation and slip of an immense mass of the strata, which forms a substantial table in this natural alcove. At Kelhead the *Orthoceratite*, *Productæ*, *Spiriferæ*, *Bellerophon apertus*, &c., are in abundance, and exceedingly perfect.

About five miles north of the extreme end of the Dumfries sandstone is the Closeburn Basin, in length about ten miles, and from three to five in breadth; between them is a zone or band of grauwacke or Upper Cambrian rock. The northern terminus is near Collaine, at the base of the Lowder mountains, which rise to an elevation of 3150 feet.

The new red sandstone is the superior stratum, and is quarried in several places. The dip is by no means regular. There are several good sections, but the best afforded are in Cree-hope Linn.

The carboniferons limestone is quarried to some extent at the eastern out-crop at Closeburn, and on the west at Bajarg.

The cabinet of Sir C. Menteith contains a fine collection of fossils of this formation, from the Closeburn quarry, amongst which are the *Orthoceras cordiforme*, and *giganteum*. The heart-shaped specimen measures nine inches and a quarter in length, and seven inches in diameter at its broadest part. This formation rests unconformably upon the grauwacke or Cambrian rocks, which entirely surround the basin, and at Comple Mill, where the superior beds are denuded, this rock is again found. This basin is made further interesting to the geologist by a basaltic dyke passing through it; a good section of its columnar structure is seen at Comple Water; it is about twenty-two or twenty-three yards wide, and ten high. Volcanic grit and altered sandstone are in immediate connexion.

The Duke of Argyle read a notice respecting the occurrence of copper veins in Argyleshire, and exhibited specimens of marble from various places in Scotland.

Fishes of the Old Red Sandstone. By RODERICK IMPEY MURCHISON, *F.R.S., F.G.S., General Secretary to the British Association.*

Mr. Murchison called the attention of the Section to the subject of the old red sandstone of the northern counties of Scotland, the general relations of which had been long ago pointed out, and some of its fossil fishes described by Professor Sedgwick and himself*. On this occasion his object was to mark distinctly the progress which had since been made in our knowledge of the structure and contents of this system in the same tract of country. In doing this, Mr. Murchison referred to Mr. Hugh Miller, of Cromarty, who, unaided, had unravelled the complicated relations of the older stratified deposits around his native place, and had first endeavoured to *describe* a singularly formed animal with lateral wing-like processes, the *Pterichthys* †, which with *Coccosteus* and other new genera of Agassiz have recently been found in considerable quantities, on both sides of the Murray Frith. Mr. Murchison then adverted to the general views of Dr. Malcolmson, of Forres, who had re-examined all the fish deposits lying between the Orkneys and Aberdeenshire, and had divided the old red sandstone of these parts into three members, the middle and lower of which are distinguished by forms of fish peculiar to each. This work, illustrated by drawings, is now in the course of publication in the Geological Society's Transactions, and will form an interesting subject of comparison with the work preparing by Professor Asmus, of Dörpat, upon similar ichthyolites, to which Mr. Murchison adverted in his communication on the geology of Russia.

Account of the Footsteps of extinct Animals observed in a Quarry in Rathbone-street, Liverpool. By JAMES YATES, *F.R.S.*

"For more than half a century a stone quarry has been worked in Rathbone-street, Liverpool; but only within a few weeks have any traces been observed in it of organic existence. On my way to the Meeting of the British Association, I had occasion to stay a short time at Liverpool, and was informed by Mr. Higginson, a surgeon in that town, that he had found in this quarry footsteps of the same kind which were discovered about two years ago at Stourton, in Cheshire. I accompanied him to the spot, and found the appearances as follows. The strata are moderately inclined, and of so great thickness as to be well adapted for building. The workmen are at this time hewing out of them a set of pillars twenty feet long, intended to form the colonnade of a public edifice. These thick strata alternate with others which are very thin, and on which the ripple-mark is sometimes seen. Lumps

* Geological Transactions, vol. iii. p. 125.

† On this occasion M. Agassiz named the prominent species *Pterichthys Milleri.*

of soft clay of the form of pebbles, such as are still formed every day on the shores of the Mersey, are found imbedded in the sandstone, and thin seams of clay are interposed between the sandstone strata. The footsteps are found on turning up the broken pieces of one of these strata; for they occur on its under surface, and are in fact casts, not original impressions. This under surface rests upon a seam of fine clay about one quarter of an inch in thickness. Without the intervention of the clay which has been deposited between the beds of sand, it is manifest that neither ripple-marks nor footsteps would have been preserved. But it appears, that soon after the deposit of a thin bed of clay upon the soft sand, amphibious quadrupeds, probably allied to crocodiles, monitors, or other saurians, traversed the shore of the then existing river, and left their footsteps impressed upon the clay. The water having again overflowed the shore, deposited a bed of sand, filling the impressions of the animals' feet, and consequently, on the induration of the sand and its conversion into stone, producing those casts which are now discovered.

"It is almost unnecessary to remark, that the Liverpool sandstone does not differ in its geological relations from that of Stourton, both belonging to the new red sandstone formation."

On the great development of the Upper Silurian Formation in the Vale of Llangollen, North Wales, and on a Plateau of Igneous Rocks on the East Flank of the Berwyn range. By J. E. Bowman, *F.G.S.*

In the course of a recent examination of the boundary line between the Silurian and Cambrian rocks in North Wales, undertaken at the suggestion of Mr. Murchison, the author came in contact with the formations that form the subject of his paper, and which do not appear on the latest geological maps. He showed, by the aid of two enlarged sections, taken on the spot and rendered more complete by data liberally furnished by Colonel Colby, of the Ordnance Office, that the shales and slates which compose the hills for some miles north and south of the vale of Llangollen, and extend westward nearly to Corwen, belong to the Upper Silurian formation. These rocks have here completely lost the character of the soft brown "*mudstones*" of Shropshire and Montgomeryshire, and in many places resemble the Cambrian series, slates and flags with perfect cleavage being extensively quarried at Glyn, Oirnant, &c. Their true geological position was satisfactorily proved, by their being seen rising from under the Upper Ludlow rock of Castell Dinas Bran, in which Mr. Bowman found *Terebratula Navicula*, *Cypricardia*, &c., and by their lowest beds reposing on the fossiliferous Lower Silurian rock of Cyrn y Brain. These proofs were confirmed by the no less conclusive evidence of fossils, *Orthocerata*, *Graptolithus Ludensis*, and *Cardiola interrupta* being found in some of the quarries.

Unlike the soft and uniform equivalents of these rocks, made familiar to geologists by the labours of Mr. Murchison, they here consist of three principal groups, which insensibly pass into each other, and

are not separated from the Upper Ludlow by the usual Aymestry limestone.

1. Blue unfossiliferous shale, rising conformably from under the Upper Ludlow, and passing into parallel thin beds of hard siliceous schist. These form the bed of the Dee for several miles above Llangollen, and their dip being in the direction of the stream, and their projecting edges being opposed to it, they give to its dark waters those alternate reaches of turbulence and repose which form the most interesting features of that celebrated river.

2. The middle group consists of a great thickness of uniform parallel beds of light blue shale, some of which, on weathering, assume a whitish colour, and give the section a streaked or banded character. These form the bold promontory of Rhysgog, and are largely developed on the steep west face of the Wriddiog, by the side of the great Holyhead road. Their lower portion is interstratified with bands of hard sonorous greywacke, and passes into the

3rd or lower group, consisting of the slates and flags which are quarried at the base of Cefn-uchaf on the south of the vale of Llangollen, and in the chain of hills on the north, as at Oirnant, &c., and are of great local and commercial value. At the north end of this chain the lowest beds repose upon the Lower Silurian rocks of Cyrn y Brain.

The total thickness of the three groups is estimated at about 3,100 feet. These rocks are compared with various recognised members of the same geological age, and of an intermediate character, from other localities, to show their connexion with the soft *mudstones* already alluded to; various other coincidences of dip, tendency to concretions, structure of joints and cleavage are cited.

Mr. Bowman next described an elevated plateau of igneous rocks, occupying an area of about twenty square miles on the east flank of the Berwyn mountains between Llanarmon Dyffryn Ceiriog and Llansaintfraid Glyn Ceiriog, not noticed in the latest geological maps. It is divided by a deep picturesque gorge, through which the river Ceiriog and the road between the two villages just named, pass. The igneous matter varies from a pure white compact felspar to a gray or greenish trap, which in places is stratified, and resembles grauwacke. It has thrown off the sedimentary rocks on all sides, and burst through them in various places, forming insulated hills of trap. Near the centre of the plateau, at the top of the hill of Pen y Craig, is a column of compact white felspar 20 to 25 yards deep and 16 to 18 yards wide, hemmed in on each side by a wall of Lower Silurian rocks, which it has rifted asunder, and overspread laterally to a considerable distance, its hardened perpendicular masses crowning the precipice like a ruined castle. Blocks of this felspar strew the surface to a considerable distance, mixed with others of stratified and amorphous trap; and others project from the rifted sides of the gorges. Some of the stratified traps so repeatedly alternate with the schists, that it is difficult to avoid the conclusion of their having been formed simultaneously; while others seem to have been forcibly injected between the hardened beds, and to have taken the shape of the intermediate spaces. The rifted

appearance of the trap in the gorges, shows that after its consolidation, the whole plateau has been broken up by a second uplift from below.

In conclusion, the author adverted to the difficulties that attend the investigation of the older stratified rocks, which are, 1st, the convulsions which have broken up the beds; 2nd, the great uniformity of the beds through vast thicknesses; 3rd, changes from igneous action; 4th, the extent to which the bedding has been obliterated by the cleavage planes; 5th, the general absence of organic remains; and, lastly, the all but universal covering of diluvium that has filled up the fissures of dislocation. Mr Bowman also visited the Bala lime quarries, and collected largely of their fossils, which, with one exception, as far as they have been yet examined, are similar to those in the Lower Silurian rocks. If, therefore, there be any boundary between the Upper Cambrian and Lower Silurian systems, it must be defined by other evidence than that of fossils. In addition to the absence of the dividing limestones of the Upper Silurian rocks, some peculiarities were pointed out in other parts of the large section exhibited, viz. the old red sandstone is entirely wanting in Montgomeryshire and Denbighshire, the carboniferous limestone resting upon the Upper and sometimes on the Lower Silurian; while to the north of Cyrn y Brain, the limestone itself is deficient, and the millstone grit reposes upon the fossiliferous Lower Silurian.

Account of a Raised Sea-beach at Woodspring-hill, near Bristol. *By* William Sanders, *F.G.S.*

Woodspring-hill forms a part of the coast of the Bristol Channel, about eighteen miles W.S.W. of Bristol, and two miles to the north of Weston-super-mare. The name which it bears on the parish map is derived from an ancient tower and other buildings, the remains of Woodspring priory. On the Ordnance map it is named Middle Hope. The hill is about two miles in length from east to west, with a breadth of about half a mile, decreasing to a point at the western end which is called Swallow-cliff. The author then describes the geographical relations of this detached hill of mountain limestone, to the carboniferous district included between the Mendip Hills and Tortworth. Within this space he describes the principal lines of displacement of the rocks, and from the evidence which he has collected concludes that, throughout this district the evidence abounds of elevatory movements during the formation of the magnesian conglomerate, and before the deposition of the new red sandstone strata, as well as of elevations that affect both the new red marls and the superincumbent lias. Besides these there have been disturbances on a much smaller scale and to a more limited extent, but leaving no other trace of the time of disturbance.

The author then describes the phænomena observed in this hill, which mark the existence of an ancient sea-beach there. These may be classed under the following heads.

1. Blocks of several feet in diameter, composed of pieces of limestone, large and small, with rolled pebbles, cemented together by broken

shells. At the same level (twenty-five feet above ordinary spring-tides) a mixed mass of fine gravel sand and shells (*Tellina solidula*, *Littorina communis*, *L. neritoidea*, *Patella vulgaris*, but no extinct species).

2. A double range of terraces and declivities, the upper one most conspicuous, which appear to correspond to the strikes of the shale and limestone beds, which form in this hill the base of the limestone series. On the upper of these, shells of the kind already noticed were found by digging to the depth of a foot.

3. A remarkable broken part in the brow of the upper terrace or inner cliff, already mentioned, a fact inexplicable by modern agency, but easily understood as the effect of an ancient slip, produced by littoral action.

From these phænomena, combined with a careful survey of the geographical features of the vicinity, the author states his conclusion to be that convincing evidence exists, that at some distant period since the complete establishment of the present order of animal life, an elevation to the extent of twenty or thirty feet has occurred along the northern coast of Woodspring-hill; and that there is also a probability that a similar movement happened at some previous date, yet still within the modern geological period. But although a connexion between the event here described and the minor movements of the district, to which allusion has been made, may be suspected, yet the author is unable to trace such relationship from want of knowing what common evidence of former position can exist under such varying conditions as are implied by inland situation on the one hand, and on the other, close contact with the sea-shore.

(Maps and sections of the hill were exhibited in illustration.)

On the Older Strata of Devonshire. By the Rev. David Williams, *F.G.S.*

The author stated that certain fossils had been discovered in the culm and plant rocks in the neighbourhood of Exeter by Mr. Parker, jun., of genera and species such as had not hitherto been found in any part of the true coal measures of England. Mr. James Sowerby had kindly examined them, and determined "five species, viz. *Nautilus subsulcatus*, *Goniatites spirorbis*, *G. reticulatus*, *G. striolatus*, and *G. Calyx*, all figured by Phillips." Mr. Sowerby stated that there were about ten other species, and a *Turbo* or *Littorina*. Mr. Williams contended that these reliquiæ, coupled with the diametrically contrasted mineral characters of the floriferous series of Devon, showed that they could not be the true equivalents of the English coal-field. In confirmation of this he appealed to the organic remains of Petherwin and Landlake, which he included beyond any doubt in the lower culm measures, and of which Professor Sedgwick and Mr. Murchison, in the London and Edinburgh Philosophical Journal for April, 1839, had stated that there was "*an unequivocal passage* between those fossilife-

rous slates and the overlying culm measures." He particularly requested attention to the fact that the Petherwin slates and limestones, in the examination of them by Professor Phillips, as reported by Mr. De la Beche, had not been shown to contain one mountain lime species; and the utmost that Professor Sedgwick and Mr. Murchison, aided by the accurate discrimination of Mr. Sowerby, could elicit from them, was that " one or two of them very nearly resembled mountain lime fossils." Mr. Williams moreover stated that he had obtained the conclusive evidence *of the fact* that the Cornish killas overlaid the plant and culm rocks, which he contended annihilated at once the two hypotheses to which he objected, viz. the proposed identification of those rocks with the English coal-field, and the classification of the killas and Exmoor group as the old red sandstone. That the plant and culm rocks were subordinate to the killas, was shown not only by the fact of the former being brought up through the northern borders of the latter, in a great anticlinal line, but by observations made by Mr. Williams this summer, that nearly the whole of Dartmoor was invested by the lower culm measures, which everywhere dipped away from it below the killas and coral limestones. The proportion of carboniferous fossils from the South Devon slates and limestones, enumerated by Mr. Lonsdale in his late valuable memoir on that region, Mr. Williams contended did not justify the arranging those rocks, even in so close an approximation with the mountain limestone as the parallel of the old red sandstone. He also remarked on the total absence from the Devonshire strata of those numerous and characteristic species of fishes which had been found in the red sandstone so extensively in England and Scotland, and, as Mr. Murchison's recent researches had proved, even in Russia.

Mr. Williams referred to a diagram and specimens of the hitherto considered "granite veins," from the bed of the Erme river, north of Ivy-bridge, which he referred to a tranquil fusion and conversion of the sedimentary rock, and not to injection.

On a Pleistocene Tract in the Isle of Man, and the relations of its Fauna to that of the neighbouring Sea. By EDWARD FORBES, *F.L.S.*

Mr. Forbes stated that he did not appear as a geologist, but as a zoologist desirous of contributing to the progress of geology. In the course of his investigations with the dredge, he was frequently led to compare the present state of the sea with that of the land bordering it, and the results were such as mutually illustrated geology and zoology. The northernmost part of the Isle of Man, left white in Mr. Greenough's map, is composed of a great bed of pleistocene sand and marl, called by the people *red marl*, to distinguish it from the white marl, which fills up basins in the former, and in which the bones of the fossil elk are found. The red marl is marine, the white marl of fresh-water origin. The pleistocene tract so composed extends from the slate mountains to the sea, terminating in high cliffs of sand and clay. The portion immediately bordering the mountains is

composed chiefly of sand, and in it there are no organic remains; that furthest from the mountain is red marl, and the remains of shells are found in beds in it. These shells are associated together exactly as those are which at present exist in the neighbouring sea. There is even an exact correspondence between the elevated tertiary tract and the present sea bottom. The latter for from two to four miles from the shore is composed of sand with groups of boulders, to which laminariæ are attached, thinly scattered in places. Beyond the sand commences a great bed of living shells on a clayey or gravelly bottom, exactly corresponding to the position and nature of that part of the marl in which the shells are found. In the marl the shells most abundant and characteristic are *Nuculæ*; which also occur on the shell bank; but there is also this important difference, that the species are not identical. The *Nucula oblonga* characterizes the fossil bed, the *Nucula margaritacea* the recent. The pleistocene bed appears to correspond exactly with those of Cheshire and the Clyde. Near Ramsay it is bordered for about one mile by a triangular tract of gravel and clay. This tract was formed within the memory of man, in consequence of changing the course of Culby river. It is most interesting in a geological point of view, as it presents all the appearance of a pleistocene clay-bed, containing shells now extinct on the Manx shores, for the diversion of the course of the stream has caused the destruction of *Listera compressa* and *Tellina solidula*, two shells not now found alive on that shore.

Mr. Forbes concluded by illustrating the importance of the dredging researches now going on, by the circumstance of the committee having this summer settled the question of the identity of *Phytocrinus* with *Comatula*, the sub-committee engaged in dredging on the coast of Ireland having fully proved the former animal to be the young of the latter.

On the Stratified Deposits which occupy the Northern and Central Regions of Russia. By Roderick Impey Murchison, *F.R.S., F.G.S., General Secretary to the British Association, and* E. de Verneuil, *Membre de la Société Géologique de France.*

Mr. Murchison, accompanied by M. E. de Verneuil, having just completed a tour of considerable extent in the northern and central districts of Russia, undertaken with a view to determine the general relations of the *Palæozoic* or older stratified deposits of that empire, took this first opportunity of giving a brief outline of the chief results at which his friend and himself had arrived, in anticipation of an extended memoir, which they purpose to prepare in the ensuing winter, and which will be read before the Geological Society of London.

The geologist accustomed to the diversified outlines which characterize those countries of Europe in which the older sedimentary rocks exist, and who has often had great difficulty in working out their succession and classification, in consequence of the disturbances and alterations to which they have been subjected, is surprised to find in Russia these strata spread in horizontal, unbroken sheets over so wide a portion of the earth's surface; each great formation trending for

immense distances, with few or no alterations in its mineral characters, or organic remains.

Two great difficulties, however, are opposed to the examination of this region,—the slight altitude of the masses above the sea, and the vast quantity of *drift* or superficial detritus, which obscures the fundamental rocks. To conquer these difficulties, the authors examined, in succession, all the principal banks of the rivers between the longitude of St. Petersburgh and that of Archangel, which, flowing from N.N.E. to S.S.W., might be expected to offer the evidences they required; and having ascended the great Dwina, from the White Sea to Oustiug Veliki, they afterwards extended their researches to the south of Nijnii Novogorod, and the edges of the province of Tambof, in order to determine the relations of the secondary rocks to those older deposits with which they had become familiar.

The formations were found to succeed each other in the following *ascending order*:—

1. *Silurian Rocks.*—The oldest stratified deposits of Russia (those on which St. Petersburgh is situated) are clays, sandstone, limestone, &c., which, from the organic remains they contain, must be considered the equivalents of the Silurian system of the British Isles. The detailed order of these beds "*per se*," was long ago accurately given by Strangways; but at the early day when he wrote, the study of organic remains was not sufficiently advanced to enable him to determine their place in the geological series, nor to point out their true relations to the adjacent masses. Many of the organic remains have been described by the native authors, Eichwald and Pander, and some very characteristic forms very recently by M. de Buch, from specimens sent to him by Col. Helmersen. These Silurian deposits occupy the islands of Öland, Gothland, &c. in the Baltic, and trend along the shores of Courland in a broad band from W.N.W. to E.N.E., till they are lost under vast heaps of granitic detritus between the lakes Ladoga and Onega. Near the latter lake these deposits are deflected to the north, and there meet with great ridges of trappean rocks, which run from N.N.W. to S.S.E. In that region all the deposits are in a metamorphic condition; the limestones present few distinct traces of fossils; and the authors having satisfied themselves that there was no chance of observing any further evidence of a descending order between such rocks and the great primary granitic chain of Scandinavia and Russian Lapland, the boundary of which they coasted, confined their attention to the *ascending* order of the strata.

2. *Old Red, or Devonian System.*—That the inferior strata were the true equivalents of the Silurian system, was determined not only by their aspect and fossil contents, but by their passing into other overlying rocks which are completely identical with the "Old Red System" of the British Isles, as defined by Mr. Murchison*. This system is of enormous extent in Russia; ranging from the borders of Poland Lithuania is chiefly composed of it, and Dörpat is in its centre. It thence passes by the lakes of Ilmen and the Waldai Hills, and is extended over a vast region to the E.N.E., where it constitutes a large

* See Silurian Researches, p. 165, and Table with the Map.

portion of the shores of the White Sea. This system consists of flagstone, clays, marls, cornstones and sandstones, the whole bearing a considerable resemblance to the red deposits of the same age in our isles, from which, however, they differ in containing copious *salt springs*, and much *gypsum*. It was the occurrence of so much salt and gypsum, that led previous writers to consider these deposits an equivalent of our new red system, which, being found to contain these minerals in our own parts of Europe, had been even termed by some, the saliferous system. That the red deposits (red and green) are, however, the true equivalents of our old red sandstone, is demonstrated, not only by order of superposition, but also by the many organic remains which they offer. Fishes are the distinguishing fossils of this great Russian system, and among these are species (notably the *Holoptychius Nobilissimus*, Murchison, with *Coccosteus*, *Diplopterus*,) and other forms which occur in deposits of the same age in Scotland. These fishes are in abundance, and a beautiful work, illustrative of them, is now preparing by Professor Asmus, of Dörpat. The authors have traced these fish-beds for many hundred miles, and occupying several stages in the system, each stage characterized by peculiar species*.

The zoological contents of this system are also of great value in illustrating and confirming the palæozoic classification proposed by Messrs. Sedgwick and Murchison; or in other words, the evidences found in Russia leave no doubt that the old red and Devonian systems of rocks are identical. *Terebratulæ*, *Spirifers*, *Euomphali*, *Bellerophons*, and other shells distinct from those of the carboniferous system, but similar to those which occur in Devonshire, Westphalia, Belgium, and other places (in deposits which have been shown by these authors to be of the age of the old red sandstone), are associated in Russia with the *fossil fishes of the old red sandstone* of the British Isles.

3. *Carboniferous System*.—In the northern regions of Russia, the lower or calcareous part only of the carboniferous system exists, and it is seen in many places to overlie the old red sandstone. The inferior beds consist of incoherent sandstones and bituminous shale, which sometimes contain thin beds of impure pyritous coal, and impressions of several plants well known in the carboniferous system of our own islands. These are surmounted by various bands of limestone, the lowest of which only have occasionally some mineralogical resemblance to the mountain limestone of Western Europe; other beds being lithologically undistinguishable from the magnesian limestone of England; others from a pisolite; a third and very prevalent band of considerable thickness is milk-white, and not more compact than the calcaire grossier of Paris. This white Productus limestone was traced by the authors from the neighbourhood of Moscow to beyond Archangel (and they ascertained that it ranged far into the country of the Samoiedes), a distance of not less than 1000 miles. This formation

* Professor Agassiz being present at the meeting of the Association, confirmed the views of the authors. In the red and green beds which underlie the carboniferous strata, a remarkable bone-bed contains scales of *Holoptychius*, *Coccosteus*, *Diplopterus*, so characteristic of the old red sandstone of Scotland.

has also a mineral resemblance to chalk, in being loaded with thin bands of flints, sometimes concretionary, in which corals occur. Associated with this formation, on the banks of the Dwina, about 200 wersts above Archangel, and south of Süsskaia, are splendid bedded masses of white gypsum, which, for many miles, present at a little distance all the appearance of white limestone. With these grand gypseous deposits, in which are occasionally large concretions, alternate two or three thin bands of limestone, in one of which the authors detected fossil shells (*Avicula*) which are new to them. This and other peculiar bands near Ust-Vaga, which are rather higher in the series, will be described hereafter, when the fossil shells have been examined.

The carboniferous limestone of Russia is highly fossiliferous, and from the normal and unaltered condition of most of the beds, the fossils are generally in an excellent state of preservation. Among them are many well-known British species, the lower beds being distinguished by the very same large *Productus hemisphericus*, so well known in the isle of Arran, and other parts of England and Scotland; and the white beds being loaded (among some new forms described by Fischer) with many of the species published by Phillips and by Sowerby, as well as by several characteristic corals (*Chætites radians*, &c.).

Owing to its mineral aspect, this rock has also, till within the last year, been much misunderstood; but Colonel Helmersen having observed its position in the Waldai Hills and its association with the coal, and having ascertained the nature of the fossils from M. Von Buch, he first gave out that, in that district, it must be considered the true mountain limestone. The authors have completely confirmed this view, by ascending and descending sections, and have very largely extended it.

4. *Newer Red Formations.*—The extent to which the authors are inclined to believe in the existence of newer red deposits, and their explanation of what they believed to be a vast basin in the governments of Vologda, Nijnii, Kostroma, &c., was reserved for a future occasion.

5. *Oolitic or Jurassic Series.*—When the authors visited Russia, it was still a great problem whether there was, or was not, a series of strata to connect the lower carboniferous strata above described with certain rocks of the oolitic series, which have been long known to exist in the south of Russia, and some of the fossils of which were sent to England by Mr. Strangways.

Some of these beds, which rest at once on the great red formation along the banks of the Volga, between Kostroma and Nijnii Novogorod, belong unquestionably to the middle oolite, as they contain *Ammonites* and *Belemnites* identical in species with those of the Oxford clay and "Kelloway Rock" of Smith. Other shells found near Jelatma and Kaccimof and Moscow had been collected; but on this point Mr. Murchison reserved his opinion till the examination and comparison of the organic remains had taken place in London.

At Moscow, Jelatma and Kaccimof, however, there is no ambiguity, for there these shales of the oolitic system, some of the fossils of which resemble those of the lias, rest at once on the white carbonife-

rous limestone without the intervention of any other strata,—a fact of great theoretical interest to geologists, and of practical importance to the Russian empire.

6. *Ferruginous Sands.*—The shales of the oolitic series are covered by ferruginous sands, which here and there contain large flattened concretions of grit, which, near Moscow, are used for millstones; but never having observed fossils in this rock, the authors are unwilling to hazard an opinion regarding its age. With the exception of certain very recent deposits, these grits are the youngest solid strata in the northern half of Russia in Europe.

7. *Chalk.*—The cretaceous system is largely developed in the south, and in the Crimea; but on this occasion the authors did not extend their tour to the chalk districts.

8. *Tertiary Deposits.*—The white shelly limestone of Crimea, and its relations to the underlying chalk, have already been described by one of the authors. Such deposits have not yet been discovered in any of the northern or central regions of Russia.

9. *Younger Pleiocene* (*Pleistocene*).—It was formerly the general belief, that the great masses of superficial detritus, whether clays, sands or blocks, which cover so very large an area of the northern region, were all referable to an epoch (diluvian) in which the bones of the great extinct quadrupeds were also imbedded. The duration of their journey was not sufficient to enable the authors to make many distinctions of age between these different masses; but they have unquestionably commenced this division by the discovery of beds of clay and sand on the banks of the Dwina and Vaga, upwards of 200 miles south of the White Sea, which contain fifteen or sixteen species of shells, many of which still preserve their colours, and which, having been referred to Dr. Beck, of Copenhagen, have been all pronounced to be of *quasi* modern species. Mr. Lyell confirms this identification, and states, that they are identical with the Uddevalla group. This discovery, in which they were assisted by Count Kayserling, who accompanied the authors in a part of their tour, is conceived to be of high geological interest, as it demonstrates that, during the modern period, the whole of the vast flat country of north-eastern Russia was beneath the sea for a considerable time, the eastern boundary of that sea being the Ural Mountains.

10. *Drift and Erratic Blocks.*—Overspreading all the formations, and greatly obscuring them, is a vast mass of detritus, the large granitic blocks of which have excited much attention, from the days of Pallas to the present time. This detritus, which has all been derived from the north, was shown to have been deposited *under the sea*, since it covers the above-mentioned shells. This portion of the subject was slightly adverted to, its consideration and that of all the superficial phænomena (including the parallel striæ near Lake Onega, &c.) being deferred to a future occasion. The important work, however, of M. Bötlingk was cited.

In verbally illustrating this wide field of inquiry, Mr. Murchison took occasion to state, that he was very much encouraged to undertake the journey to Russia through the suggestions of M. L. von Buch,

* M. E. de Verneuil.

who, from an examination of certain fossils sent to him from thence, had become convinced *à priori*, that the same palæozoic succession would there be found as in the British Isles. Mr. Murchison gratefully acknowledged his obligations to the Baron A. von Humboldt, and dwelt with pleasure on the assistance which his fellow-traveller and himself received from the Baron A. de Meyendorf, now executing, by order of His Imperial Majesty, assisted by M. Zenofief, a statistical survey of parts of Russia, who endeavoured to make his tour correspond to some extent with that of the authors, and who enriched his expedition with two excellent naturalists, Count Kayserling and Professor Blasius. Mr. Murchison further took this public opportunity of testifying his sincere thanks to the Russian authorities who aided this geological inquiry, among whom he particularly enumerated their Excellencies the Count de Cancrine, Count Nesselrode, Count Alexander Strogonoff, Baron Brunnow, and General Tcheffkine*. And he further expressed his sense of the value of the services of a zealous young geologist, Lieutenant Koksherof, without whose aid the authors could not have accomplished their task. Maps and a section illustrated the description, and selections of the characteristic fossils of each group were laid upon the table.

On the Yellow Sandstone, and other points of the Geology of Ireland. By R. Griffith, *F.G.S.*

Mr. Griffith exhibited his new corrected map of the geology of Ireland, and a series of specimens in illustration and confirmation of several changes, especially in the south of Ireland, which he had thought it right to make since the first appearance of the map. A feature of the map, of much importance, was the subdivision of the mountain limestone series, and the extension of the colour for millstone grit over districts formerly classed as true coal measures. The yellow sandstone was particularly described in different districts, and specimens, in a regular series, of the organic remains in the Silurian and Carboniferous groups of Ireland, were exhibited to the Meeting.

On the occurrence of two Species of Shells of the genus Conus, in the Lias, or Inferior Oolite near Caen, in Normandy. By Charles Lyell, *F.R.S. G.S.*

Fossil shells of Lamarck's family "Enroulées" abound in many tertiary formations, but scarcely any examples are recorded of their occurrence in older strata. The six genera comprised in this family are *Ovula*, *Cypræa*, *Terebellum*, *Ancellaria*, *Oliva*, and *Conus*. Four of these appear never yet to have been found, either in the chalk or any older rock. Of *Cypræa*, one species has been discovered in the upper chalk of Faxöe, in Denmark; and M. Dujardin obtained from the chalk, near Tours, a Cone, which he has called *C. tuberculatus*.

* General Tcheffkine, Major-General of the School of Mines at St. Petersburgh, and Professor Jacobi, of the Imperial Academy of Sciences, were present at the Glasgow Meeting.

Two other species of this genus, purporting to come from the lias near Caen, were seen lately (June 1840) by Mr. Lyell, in the private collection of Professor Deslongchamps and M. Tesson, of that city. A brief notice had been previously given of their discovery in a report of a meeting, held in 1837, by the Linnæan Society of Normandy. To satisfy himself of the correctness of the alleged geological position of these Cones, Mr. Lyell visited, in company with M. Deslongchamps, one of the localities called Fontaine Etoupe-Four, about six miles south of Caen. He found there a stratified limestone, containing *Ammonites*, *Belemnites*, *Pleurotomariæ*, and other Mollusca and Crinoidea, resting unconformably in horizontal strata on highly inclined quartzite and talcose schists of the transition formation. Many deep rents occurring in the fundamental rock were filled with the limestone, and in these situations shells in great abundance, together with broken pieces of quartzite, are united into a breccia by a calcareous cement. Most of the Cones have been found in these rents, and the matrix in which they occur constitutes the oldest portion of the incumbent or fossiliferous formation. In regard to the age of this last, some of the shells, such as *Ammonites planicosta*, and *A. Bucklandi*, occur in the lias of England; others are met with in our alum shale, and inferior oolite. The specimens collected by the author, or which were presented to him by M. Deslongchamps, have been examined by Mr. Lonsdale, of the Geological Society of London, who, judging by this evidence, considers the formation to be either an upper member of the lias, or to be intermediate between the lias and inferior oolite. M. Alcide D'Orbigny has also collected forty or fifty species of fossils from the limestone of the same place, and he refers them to the upper lias, although a great proportion of the shells are new, and some do not even belong to any genera hitherto established. The stone in which the Cones are imbedded is of a pale brown ferruginous colour, like ordinary inferior oolite, but precisely resembling, according to Mr. Lonsdale, the gritty *lias* or corn-grit of Radstock. Some of these Cones were first discovered by M. Deslongchamps, and M. Tesson soon afterwards obtained the most perfect specimens, of which last drawings were made by M. Deslongchamps, and presented to Mr. Lyell for publication. The originals have also been examined by Mr. George Sowerby, and they seem to be all referable to two very distinct species, one of which has been named *Conus concavus*, in which the spire is so depressed that the summit is concave. For the second, the name of *Conus Cadonensis* is proposed. It approaches nearest to *C. antediluvianus*, varying considerably in the height of the spire in different individuals.

On ancient Sea Cliffs and Needles in the Chalk of the Valley of the Seine in Normandy. By C. Lyell, *F.R.S. G.S.*

The observations in this paper are principally confined to that part of the winding valley of the Seine which extends from Andelys to Elbœuf, a distance by the river of about thirty miles. This valley, which is from two to four miles wide, has been excavated through chalk with flints horizontally stratified, about 300 or 350 feet in thick-

ness, and a mass of overlying tertiary sand, gravel and clay, from 30 to 100 feet thick. The last-mentioned deposit constitutes a level platform, differing wholly in character from the chalk downs in England, but the slope of the hills bounding the Seine and its tributaries, where the chalk crops out, corresponds exactly in character with the escarpments of the north and south Downs in England. There is however, this distinction, that the escarpments of the valley of the Seine, which are distant from two to four miles from each other, are broken at certain points by ranges of vertical and even overhanging cliffs of bare white chalk with flints, and by occasional needles and pinnacles of chalk. Mr. Lyell first refers to several natural precipices of chalk which occur, some on the right and some on the left bank of the Seine, above Andelys, or between that town and Meulan, about fifteen miles in a straight line from Paris. In one of these localities, near Bonnières, two distinct cliffs are seen one above the other. He then described more particularly a great range of cliffs about two miles long at Andelys; secondly, another range and some pinnacles at Vatteville opposite Tournedos, and at Senneville; and thirdly, the cliffs of Elbœuf or Orival.

In regard to the first of these ranges, it commences on the right bank of the river at Le petit Andelys, and includes the rock on which stands Chateau Gaillard. The base of the range is generally about fifty feet above the alluvial plain of the Seine, from which it is separated by a steep green slope, resembling in outline a talus of fallen debris, but in many places composed of solid rock. The cliffs themselves vary from fifty to 100 feet in perpendicular height, their continuity being broken by a number of dry valleys or combes, in one of which, near Andelys, occurs a detached rock or needle called the Tête d'Homme. The top of this rock presents a precipitous face towards every point of the compass, its vertical height being more than twenty feet on the side of the downs, and forty towards the Seine, and the average diameter of the pillar being thirty-six feet. Its composition is the same as that of the larger cliffs in its neighbourhood, namely, white chalk, having occasionally a crystalline texture like marble, and layers of flint in nodules and tabular masses. The flinty beds often project in relief four or five feet beyond the white chalk, which is generally in a state of slow decomposition, either exfoliating or being covered with white powder like the chalk cliffs on the English coast, where, like them, the surface of the rock was found in some places to be encrusted with common salt. In regard to the origin of this superficial salt, it is difficult to conceive that the influence of the sea breezes can extend so far, as the distance is more than thirty miles from the nearest salt-water; but on the other hand, the author could not ascertain that any saline matter was contained in the chalk itself.

Other cliffs are then mentioned, situated on the right bank of the Seine, opposite Tournedos, between Andelys and Pont de l'Arche, where the precipices are from fifty to eighty feet high; several of their summits terminate in pinnacles, and one of these in particular is so completely detached as to present a perpendicular face fifty feet high towards the sloping down. On these cliffs several ledges are seen,

which in the author's opinion mark so many levels, at which the waves of the sea encroached for a long period. There are also above the summit of all the cliffs, three distinct parallel terraces and as many cliffs, each about four feet high, which sweep round a small combe in a semicircular form, like the seats of an amphitheatre.

If we then descend the river from Vatteville to a place called Senneville, we meet with a singular insulated needle, about fifty feet high, perfectly isolated on the escarpment of chalk on the right bank of the Seine.

The third or last range of inland cliffs referred to, is situated about twelve miles below on the left bank of the Seine, beginning at Elbœuf, and comprehending the Roches d'Orival. Like those before described, it is in part overhanging, exhibits a white powdery surface, and consists entirely of horizontal chalk with flints. Its base is only a few feet above the level of the Seine, its height in some parts exceeds 200 feet. It is broken in one place by a pyramidal mass or needle, called the Roche de Pignon, which stands out about twenty-five feet in front of the upper portion of the main cliff, with which it is united by a narrow ridge about forty feet lower than its summit. Its height is about 200 feet, and like the detached rocks before mentioned at Senneville, Vatteville, and Andelys, may be compared to those needles of chalk which occur on the coast of Normandy, as well as the Isle of Wight and in Purbeck.

The author then states, that while there are in some places marks of cliffs and terraces at six or more distinct levels, there is sometimes only one range of cliff, which may be either a few feet, or more than 200 feet in vertical height; and on the other hand, there is often no outbreak of bare rock or precipice, as is well exemplified in that part of the valley where the Côte des Deux Amants faces that of Pont St. Pierre. The cliffs, where they do exist, are usually confined to one side of the river, whether on the right or left bank. Various causes are assigned for this partial occurrence of cliffs, and the variety of their number and elevation where they exist. It is assumed that the valley of the Seine was excavated by the waves and currents of the sea, during the slow and probably intermittent upheaval of the land. When the denuding operations therefore were in progress, the valley constituted the channel of the sea between two islands or opposite coasts. Considerable cliffs would be formed at those points only against which the waves and currents set with peculiar force. Being thus originally partial, they subsequently became more rare by the obliterating action of frost and rain. A series of smaller cliffs would often be united into one when the undermining force of the sea caused it to encroach greatly at a certain point.

On Glaciers and Boulders in Switzerland. By Professor Agassiz.

M. Agassiz particularly drew attention to *facts* relative to the manner of the movements of glaciers, which he attributes to the introduction and freezing of water in all their minutest fissures, whereby the mass of

ice is continually expanded. The effects of the movement, produced by this expansion, upon the rocks beneath the ice, are very remarkable. The bases of the glaciers, and the sides of the valleys which contain them, are found to be polished and scratched by stones fixed in the lowest region of the moving ice. The fragments of the rocks that fall upon the glaciers are accumulated in longitudinal ridges on the sides of the ice, forming deposits of stony detritus, which are called lateral *moraines*. As these descend into lower valleys, they assume a central place on the moving ice, and are called medial *moraines*. As the glaciers are continually pressed forwards, and often in hot summers melted back at their lower extremity, it results that the polished surfaces, occasioned by friction on the bottom and sides, are left uncovered, and that terminal *moraines*, or curvilinear ridges of gravel and boulders, remain upon the rocks formerly covered by the ice. Thus we can discover, by the polished surfaces and the *moraines*, the extent to which the glaciers have heretofore existed, which is much beyond the limits they now occupy in the Alpine valleys. It is stated to result from similar *facts* observed by Professor Agassiz, that enormous masses of ice have, at a former period, covered the great valley of Switzerland, together with the whole chain of the Jura, the sides of which, facing the Alps, are also polished, and interspersed with angular erratic rocks, disposed like boulders in the *moraines*; but since the masses of ice were not confined between two sides of a valley, their movements were in some respects different, and the boulders were not deposited in continuous ridges, but dispersed singly over the Jura at different levels. Professor Agassiz proposes the hypothesis that at a certain epoch all the north of Europe, and also the north of Asia and America, were covered with a mass of ice, in which the elephants and other mammalia found in the frozen mud and gravel of the arctic regions, were imbedded at the time of their destruction. The author thinks that when this immense mass of ice began quickly to melt, the currents of water that resulted have transported and deposited the masses of irregularly rounded boulders and gravel that fill the bottoms of the valleys; innumerable boulders having at the same time been transported, together with mud and gravel, upon the masses of the glaciers then set afloat. Professor Agassiz announced that these facts are explained at length in the work which he has just published, *Etudes sur les Glaciers de la Suisse*, illustrated by many large and accurate plates, which were laid before the Geological Section.

On the Geology and Mineralogy of Canada.
By Capt. BADDELEY, *R.E.*

The object of the communication was to draw attention to the propriety of undertaking a geological and mineralogical survey of Canada. For this end the author pointed out the advantage of such surveys in general, and the especial use of undertaking the survey of Canada, whose mineral resources had received little development. Iron, lead and copper exist in different combinations, and probably or certainly, in

abundance, the most promising district for enterprise being that which is conterminous with the known mining tracts of New York. A specimen of native gold, weighing two ounces and a half, and having a specific gravity of 15·71, was found recently in the bed of a stream running into the Chaudiere. It was nearly of the size and shape of a pigeon's egg. A smaller specimen had been picked up a few years before near the same place. The district contains talcose and clay schists, quartz in veins or in mass, and greenstone. Except in a few spots bordering the coal-field of New Brunswick, the newest rock of Lower Canada is the carboniferous limestone. West of Toronto and toward Lakes Erie and Huron in Upper Canada, saliferous and gypsiferous marls appear, and shales with vegetable impressions and petroleum; many trials for coal through the saliferous band have been unsuccessful.

Remarks upon certain Geological Features of the River St. John in New Brunswick, with an Account of the Falls upwards from the Sea, which occur near its Embouchure in the Bay of Fundy. By James Robb, *M.D., Professor of Natural History, King's College, New Brunswick.*

There are rivers and lochs into which the tide entering gives rise to a kind of fall upwards against the ordinary course of the stream, but nowhere in the world is the phænomenon of *a fall up a river* to be so clearly seen as at the falls near the mouth of the river St. John, in the province of New Brunswick. The steamers from and to Fredericton (the head quarters of the executive government in New Brunswick) pass through the falls, but passengers always go to and from them above the broken water. The rocks of the vicinity consist of graywacke or transition slates, alternating with limestone, sometimes crystalline, and rarely holding any fossils. Above the falls a mass of sienite protrudes and alters both the chemical nature and mechanical arrangements of the stratified rocks. The slates and limestones are almost all vertical, and the strike is about N.E. and S.W. The St. John River cuts these across almost at right angles. Further up the river are stratified rocks corresponding in part with those of the coal measures in England. These are nearly horizontal, and lie upon the more inclined slaty strata mentioned above. When the river runs over the sandstones and grits, its course is equal and slow; but when it gets among the slates, disturbed and tormented by granite and sienite, its flow is violent and impetuous. About 250 miles higher up there is a very fine fall of seventy-five feet, and a headlong rapid of more than a quarter of a mile at the bottom of a most magnificent ravine. These upper falls are over black calcareous slates, highly inclined, and so easily acted on by the water, that the line of the fall can be readily ascertained to have been carried back for a considerable distance. For the remaining 300 or 400 miles of its course there are no falls on the river St. John, but there are several powerful rapids. The headwaters rise in a flat country among swamps and sandy plains,

where a rise of ten or twelve feet in the level of the water would flood a district of, perhaps, forty or fifty square miles, so flat is the country. A most remarkable feature in this great river-valley is the distinctness and regularity of the alluvial terraces to be seen wherever the banks are not too rocky and precipitous. This holds in regard both to the main river and to all its tributaries. Where these latter join the main river they are always to be seen; and what is equally remarkable, most of the tributaries, as well as the principal river, have falls at or near their embouchure.

The author has seen such terraces on all the other rivers of New Brunswick, on the salt marshes at the head of the Bay of Fundy, on the rivers of Nova Scotia, on the St. Lawrence, on the Ottawa, on the Great Lakes, upon the Hudson, the Potomac, and on all the Atlantic rivers of the northern and middle States,—terraces formed of loose detrital matters, and evidently indicative of the levels at which the water formerly stood in these rivers. The author views these terraces, and the numerous and well-known examples of the same phænomena in the Old World, as affording the most palpable evidence of a recent and general rising of land in all the countries where they occur, or at least where their existence cannot be explained upon other and ascertainable grounds. The author then describes more minutely the circumstances attending the falls of the river St. John, from notes taken by the Rev. Mr. Coster, Rector of Carleton, who has had daily opportunity of examining the facts.

I. 1. The river St. John takes rank among the third or fourth class of American rivers, and among the first or second class of European rivers. It rises far in the interior of the province, among the highlands which form the N.E. termination of the Alleghany Mountains. The Chaudiere, St. Francis and Etchenine fall off on the Canadian side; the Connecticut, Penobscot and Kennebec again fall off toward the Atlantic; while the St. John, after a course of 500 or 600 miles, and draining about two thirds of the whole province, falls into the Bay of Fundy. The flourishing city of St. John is built on a projecting mass of slate and limestone rocks, on the left bank, just where the river falls into the bay.

For the first seventy miles it is navigable for vessels drawing any depth of water: after passing the shoals at the mouth of the river Oromocto, which in dry seasons become rather shallow, it again becomes navigable for schooners for a further distance of thirty miles; after this it is still navigable for two or three hundred miles for small boats and canoes. Ships of six hundred tons burden are sometimes built about Fredericton, which is eighty-three miles above St. John. Some idea may thus be formed of the quantity of water which the St. John river contains.

2. At the confluence of the St. John and Kennebekasis, about five miles above the falls, and for about five miles further up, the St. John spreads itself into a very spacious bay of an irregularly triangular figure, which, at its greatest breadth, will probably measure ten miles. Below this bay, which is called *Grand Bay*, the river makes an abrupt turn

and pursues its course through the *Narrows*, after this it again forms a lake-like basin called *Above the Falls*. The outlet of this basin, which is contracted on one side by the projection of a point of land, and on the other by several islands to a breadth of less than a quarter of a mile, form what is called the *Upper Falls*. Through this the water forces its way and then forms a circular basin, vulgarly called *The Pot*, the transverse and conjugate diameters of which each measure nearly three quarters of a mile. The outlet of this basin is a narrow opening, measuring, at low water, 310 feet between the two opposite calcareous cliffs called *East* and *West Head*. At the foot of the latter is a large piece of rock projecting beyond the cliff, and called the *Split Rock*, which affords a passage for the water within it, at and after one-third tide. This small outlet is the *Lower Falls*, and through it all the waters of this magnificent river, which at the distance of 100 miles up measures nearly a mile across, and averaging ten or twelve feet in depth even there, rushes with inconceivable strength and grandeur. Below the falls the river again turns abruptly and increases to a breadth averaging from 800 to 1200 feet. About a mile and a half below the falls an island, called *Navy Island*, divides it into two channels, the smaller of which is dry at low water: below this island again lies the harbour of the city of St. John, though in this paper the whole space below the falls is designated as the harbour. About five miles below it the river enters the Bay of Fundy.

3. Like all rivers the St. John is at some times more full than at others. In the spring of the year, however, it is always remarkably swollen by the *Freshet*—the melted snow from the forests and high grounds increased by the periodical rains of the season. At that period the river rises thirteen or fourteen feet above its summer level, and this rise exercises a very great influence on the direction of the motion of the water at the falls.

II. A large body of the immense current called the *Gulf Stream*, is forced up the Bay of Fundy. As this bay is fully wider at its southern end, high tides are formed along the coast, and those get higher, according as the place is further up the bay. The tide outside the bay rises about seven to ten feet, and at the top of the bay, at spring-tides, with a high S.E. wind, the rise is as much as forty-five or fifty feet. The ordinary account in books of the tides of the Bay of Fundy is exaggerated. The sea water then rushes with great force into the tide rivers: at the top of the bay, where the Peticodiac enters, the violence of the tide is irresistibly great. In fact, at one place on this river, called very properly *The Bend*, the tide advances with a noise like thunder, and often overtakes animals, or upsets and buries schooners not prepared to *ride the Boar's back*, as they say, that is, to run on with the moving wall of water. In the harbour of St. John the tide rises at neap-tides to the height of twenty-six feet, and at spring-tides to that of twenty-five feet.

III. When the river is at its greatest height in the spring, and when the harbour is also at its greatest height from the prevalence of spring-tides, at high water the water of the river above the falls will be on a

level with that of the harbour below the falls. It will therefore happen, that at the time of low water, the water in the harbour having sunk thirty-five feet, there will be a fall downwards at the falls to the extent of thirty-five feet, partly at the upper fall, but mostly (on account of the greater contraction) at the lower fall. As the tide flows the fall will diminish gradually; and again during the ebbing of the tide from the bay, the falls will gradually increase until low water. So rapid and violent is the motion of both currents, when the tide is rising, that the river stream is lifted up, as it were, above the salt water, and flows away down the harbour, while the salt water forces itself upwards below the river current. The river stream only loses itself in the salt water five or six miles further out to sea. In the height of summer the water in the river is at its lowest, that is, fourteen feet lower than in the preceding case, being twenty-one feet above the harbour level; there will of course be a fall downwards to that extent, and this fall will continue to set down until the tide shall have raised the harbour-level twenty-one feet: at this period there will be a level and no fall either way. But as the tide rises the harbour-level continues to rise with it till a fall *upwards* takes place, the measure of which is the difference between the two levels. The fall upwards will be greatest at high water, after that it will decrease until, by the ebbing of the tide, the river is on a level with the harbour, then the fall will be downwards, and so continue till low water again.

The fall upwards seldom exceeds six feet, but owing to the irregular course of the rocky ravine in which the river runs, and to the great volume of water, it is an exceedingly striking phænomenon. The river level is not raised more than fifteen or eighteen inches at high water; but the water in The Pot is six feet above the level of the water above the falls.

There is a difference of nine feet in the rise of the tide at spring-tides and neap-tides; the tides rising rather more than four feet higher at the former than at the latter period, and falling off rather more than four feet also. At neap-tides, when *the river is full*, there will be a fall downwards to the extent of rather more than four feet; on the other hand, when *the river is at its lowest*, that is fourteen feet lower than in the preceding case, there will be at high water a fall upwards to the extent of nearly nine or ten feet, alternating upwards and downwards as before described.

On the Geology of Madeira. By JAMES SMITH, *F.G.S.*

On the Geology and Fossil Fishes of North Brazil. By Mr. GEORGE GARDNER *of Glasgow. Communicated by* J. E. BOWMAN, *F.G.S.*

The province of Ceará, which forms a portion of North Brazil, is situated between the 3rd and 8th deg. of south lat., and the 37th and 41st of west long. It is of an oblong form, its greatest length being

about 100 leagues from north to south; and its width varying from 50 to 70 leagues. It is bounded on the north by the Atlantic Ocean, and on the west by a low mountain range, which separates it from the great inland province of Piauhy, and consists for the most part of sandy or gravelly plains, which remind the traveller of the descriptions of the Pampas of Buenos Ayres. Boulders of granite, gneiss and quartz, sometimes of four feet diameter, and more or less rounded, occasionally occur; and here and there a low ridge of gneiss rock crops out, dipping at a very high angle to the N.W. For many leagues from the coast, the characteristic and prevailing vegetation of the plains is a beautiful species of palm, called Carnahuba by the Brazilians (*Corypha cerifera* of Martius), while that of the ridge of gneiss consists of various Cacteæ (of the genus *Cereus*) and a large Bromelia. At a distance of about eighty leagues from the north coast, and ten leagues below the Villa do Icó, the nearly monotonous level of the country is broken by a mountain range, which makes its appearance to the eastward. This is the Serra de Pereira, which runs S.W. and N.E., and is sixteen leagues in length, and its greatest height about 1000 feet above the surrounding plain. Its S.W. extremity is entirely of gneiss, but at its base is a coarse red conglomerate, containing rounded fragments of both primitive and secondary rocks.

The country between Icó and the small Villa do Crato, thirty-four leagues to the S.W., is of a more hilly undulating character; more abundantly wooded, and only occasionally opening into the large campos or plains of the north. In this tract, gold has been found in small particles interspersed in a dark-coloured diluvial soil, near the Rio Jaguaribe, but not in sufficient abundance to repay the speculators. At about eighteen leagues south of Crato, the gneiss rocks are replaced by a gray-coloured primitive clay slate, and at the termination of this, the secondary stratified series begins, the few rocks occurring from thence to Crato, consisting of a white coarse-grained sandstone. Crato stands in the middle of a large undulating valley among hills, which are the flanks or lateral spurs of the long chain which separates the provinces of the coast from that of Piauhy to the west, and which here receives the name of Serra de Araripe. The highest parts of this range do not rise more than from 1200 to 1500 feet above the town of Crato; their tops are perfectly level, and continue so for many leagues to the W. and S., forming what the Brazilians call taboleiras or tablelands. In all directions these hills consist of a white-coloured sandstone, which has sometimes a reddish tinge. In the bed of one of the largest streams, a section of the strata, to a considerable depth, exposes a bed of limestone three feet thick, beneath the sandstone, and resting upon a seam of impure coal two feet thick, which in its turn is placed upon another and lower bed of limestone. In these limestones no fossil remains could be found; the strata are all perfectly horizontal, and the level appearance of the whole Serra makes it probable they are so throughout.

About fourteen leagues to the south from Crato, is a branch or spur of this Serra, which projects ten leagues to the eastward, on the south side of which is a small villa called Barra do Jardim, situated in a

small valley upwards of a league in length, and about half a league across in its widest part. The deposit of fossil fishes (from which those now exhibited were chiefly obtained), is in an open place of the gently sloping ridge north of the villa; there the ground is covered with great abundance of rounded stones of various sizes, from that of an egg, to blocks of several feet in circumference, consisting of a light-coloured, rather impure limestone, in which lines of bedding may often be perceived, and sometimes minute shells. They split very easily, and contain portions of fishes in a more or less perfect state; by far the greatest number, however, being so much broken, that it is with considerable difficulty that tolerably perfect specimens can be obtained. The space to which these limestone nodules are confined, is not more than one hundred yards square, and scarcely any other kind of stones is to be found among them; but on every side of it, the ground is covered with other rounded pebbles of sandstone, similar to the rock of which the Serra is composed. Three other deposits of fishes occur in the neighbourhood, one about half a league to the south, a second at Macapé, five leagues to the east of Jardim, and a third at Mundo Novo, three leagues to the west. These are all on the declivity of the low hills, between the valley and the Serra, and perfectly resemble the one described, in consisting only of the rounded fossiliferous limestone nodules.

On breaking these nodules, many of them exhibit abundance of a minute bivalve shell. At Mundo Novo Mr. G. found in the same nodule a very perfect specimen of what he believes is a species of *Turrilites*, about $1\frac{1}{2}$ inch long, and a single valve of a *Venus* about half an inch in length, and in very excellent preservation. He was told by a person at Jardim, that a few years ago he found a small serpent coiled up in a stone which he had split, but this, no doubt, was a species of Ammonites. In the several hundred stones, however, which he broke in search of fish, he met with nothing of this description. These specimens Mr. G. had not sent over; neither has he accompanied those submitted to the Section by any of the sandstone of the Serra de Araripe; but from the fact communicated by M. Agassiz, that he has not yet met with cycloid fishes in any older formation than the chalk, and as far as can be inferred from the minute bivalves, it is probable that the sandstone hills in which the deposits occur, belong to that geological epoch. He states that he could nowhere find in the neighbourhood of Barra do Jardim any limestone *in situ*. This circumstance, taken in conjunction with the fact that the fossiliferous nodules show indications of stratification, and are found in detached localities, and not intermixed with those of the sandstone, which surrounds them on every side, leads to the conclusion that they occur as a bed or layer of detached concretions in the sandstone, each fish, or portion of one (for many seem to have been imbedded after being broken), having attracted round it a sufficient quantity of the lime disseminated through the mass to form a nodule*.

* This paper has since been published entire in the New Edinburgh Philosophical Journal for January 1841, with a Notice of the Fossil Fishes by Professor Agassiz.

On the Daguerreotype, as applied to the Drawing of Fossils. By J. L. B. Ibbotson, *F.G.S.*

The process proposed by Mr. Ibbotson for this purpose was explained, and specimens of its successful results were exhibited.

On the Geography of New Brunswick. By G. H. Featherstonhaugh, *F.G.S.*

The communication related principally to the methods employed in a recent survey by the Commissioners, whose report on the boundary question has been presented to Parliament. The barometers employed in measuring the heights were those made by Bunten (on the siphon construction); and towards the end of the operation, others, made by Newman, with iron cisterns.

Dr. Hannah exhibited a section of the bed of the Clyde, made by the late Mr. Logan.

Outline of Three Expeditions which might be undertaken to explore portions of the interior of Africa. By Sir J. E. Alexander.

The first to land at Cape Coast Castle, Gold Coast, proceed thence to Comassie, the capital of Ashantee, seventy miles distant, there communicate with Arab traders who come across Africa from the Red Sea, and arrange to accompany them eastward.

The second to land at Zanzibar, and accompany a caravan which arrives there annually from central Africa to trade with the warm friend of the English, the Imaum of Muscat and Zanzibar.

And the third to land at Natal, and with horses, to be procured there from the English and Dutch settlers, proceed to Delagoa in the healthy months, from May to October, and then travelling north-west, reach the Cape Colony by Lattakoo.

Additional Notes on the Wadi el 'Arabah in Syria. By the Rev. Dr. E. Robinson, *of New York.*

" The interest attached to that very remarkable fact in physical geography, which has not yet been cleared up, namely, the depression of the surface of the Dead Sea, below the level of the Mediterranean, and the drainage, probably dependent upon this depression, of a large tract of country including numerous lateral valleys, extending to the southward for upwards of 100 miles through the district termed Arabia Petræa, from the south point of the Dead Sea nearly to the Gulf of Akabah, induces me to offer a few words on the line of sepa-

ration of waters between these two basins, which may be termed a postscript to some remarks I formerly had occasion to make on M. de Bertou's account of his journey in 1838 through the Wadi el 'Arabah, from the Asphaltic lake to the Elanitic gulf*. At that time I took it for granted that the Wadi Talha of Bertou (according to his own map) was identical with the great Wadi Jerafeh, with which we had become acquainted while travelling through the western desert to Hebron, and, again, as seen from the pass of Nemela, north of Mount Hor. But on a careful construction of Bertou's itinerary by M. Kiepert, of Berlin, it appears that his Wadi Talha must be situated about two hours south of the Jerafeh, and has no connexion whatever with the latter. It would seem, therefore, to be the Wadi Abu Talha of Burckhardt. The effect of this is to move the place of the water-shed, as specified by Bertou, to a point some six miles further south than I had supposed him to mean; and if this correction be well founded, it follows that the traveller passed before, and probably across the mouth of the Jerafeh, without noticing it; although this is the great drain of all the adjacent parts of the western desert, and one of the most important and remarkable features of the whole region."

In connexion with Dr. Robinson's recent travels through Palestine, Capt. Washington exhibited a newly-constructed plan of the city of Jerusalem, correcting many former inaccuracies, pointing out several ancient sites, and showing the shading of the hills within the city, a feature not represented on any former plan.

Some Observations on Relief Maps. By M. A. Ravenstein, *of Frankfort.*

"The obvious advantages of maps stamped in relief for representing the great physical features of a country, and the probability that such maps will soon be very extensively used, induces me to offer a few words in reply to a request I have received, to state my opinion on the relief maps of M. Kummer, of Berlin. With regard to their invention, I must claim to have been the first who introduced the method of raising the hills, by means of the press or stamping, as may be seen by my "Plastic Atlas," published in 1838; it would be unjust, therefore, to attribute to Berlin that which was first made at Frankfort. It must be observed, that these are quite distinct from M. Kummer's "Globe en relief," published some years since, as that was made of papier mâché. M. Bauerkeller, of Paris, also made public, in 1839, his "Environs de Paris," in the stamped relief method, with the difference, however, that the colours are put in after the Congreve manner. In the preface to my Plastic Atlas, I anticipated that great improvements would be made; and it is due to M. Kummer to state, that he has so far succeeded, as to lead me to hope that these maps will shortly reach still greater perfection, and, when made on a large scale, will come into general use,

* See the Athenæum, No. 658.

and supersede all other maps,—and especially physico-geographical maps, without reference to political divisions; and I feel that I do but express the feeling of all interested in the advancement of physical geography, by saying that I heartily hope that M. Kummer will persevere in his efforts."

These observations were illustrated by M. Ravenstein's "Plastic Atlas," several stamped maps by Kummer, of Berlin, and a specimen of Bauerkeller's stamped and coloured plan of the city of Frankfort.

A letter was read from the Rev. Mr. Selvester, who had resided above fifty years in the Faroe Islands, expressing an opinion that the level of the coast had there undergone a depression. This was inferred from encroachments made by the sea at several points, and particularly from the fact, that on the 6th of January, 1828, full two thirds of the sun's orb had been visible above a hill near his house from the same spot, where, in 1801, he had only been able to see the upper edge of the disc.

Observations on Great Earthquakes on the West Coast of South America, particularly the great one of the 18*th of September*, 1833, *which destroyed the City of Tacna, and other places in Peru. By Mr.* MATHIE HAMILTON, *formerly Surgeon to the Potosi Mining Company.*

Tacna, an Indian town of some antiquity, now capital of the province of the same name, lies in the midst of a desert tract of about fifty miles broad, between the mountains and the sea. The port of Arica, about forty miles distant, had, since the first arrival of the Spaniards, been five times destroyed by earthquake, while Tacna had enjoyed a happy immunity, and was supposed beyond the reach of this calamitous visitation. After 1826, however, very frequent and severe shocks were felt, particularly a few weeks before the great one of the 8th of October, 1831, which reduced Arica to a heap of rubbish; yet it continued nearly uninjured till the evening of the 16th of September, 1833, when there occurred a single loud report, with an upward movement of the ground. On the morning of the 18th, there was a much more violent movement, the earth heaving at once up and down, and also laterally, accompanied by a frightful subterranean noise. The falling of houses all around, the cries of the people, the howlings of animals, produced a scene that cannot be described. The agitation seemed to have reached the utmost possible height, when suddenly the earth, as if striving to get rid of some mighty load, made a more terrible movement than ever, in every direction, and in one minute the work of destruction was completed. The cathedral in falling destroyed a numerous congregation of females, who had assembled there, and were endeavouring to escape; but the priests, who remained under an arch, were saved. It is remarkable, that while some quarters had nearly every house demolished, others were comparatively uninjured. This great movement was succeeded

by a series of slight shocks, which continued during many days. Rain (here a phænomenon) fell almost every day during six weeks; and at Arica, on the first week of October, there came down a deluge, such as had not been witnessed for half a century. The river which supplies Tacna with water, remained undisturbed; but others were changed in their courses, and one altogether disappeared. The earthquake was felt many hundred miles to the south, as far as the Desert of Atacama. At Luto, about forty miles distant, fissures were made in the ground, whence issued a dark-coloured fluid. In the province of Tarapaca, villages were overthrown, and one, which stood in a ravine, was buried, with all its inhabitants. To the north, its ravages were equally extensive. The villages of Samo, distant thirty miles, and of Loquumbo, distant sixty, were both destroyed. Moquegua, 120 miles off, suffered severe damage; and Arequipa was violently shaken, but with little injury. The effects extended even to the lofty peaks of Upper Peru. Tacora, 15,000 feet above the sea, had its church thrown down. When the atmosphere cleared after the calamity, that mighty range, as seen from Tacna, presented in many parts a new outline. Large masses had been detached or slid down into the valleys or ravines, leaving many elevated peaks denuded of their most prominent features. Mr. Scott, engineer, then employed at Ochozumo, about 14,500 feet high, describes the shocks there as terrific, and the noise, as if an immense mass of porcelain had, after being raised in the air, been then let fall and dashed to pieces. By his telescope, he saw the masses falling from the mountains, one of them leaving a space as large as St. Enoch's Square, Glasgow. On the 20th of January, 1834, a terrible earthquake occurred in New Granada, by which the large towns of Popayan and Pasto, were entirely demolished, and many thousands perished. On the 21st of September, 1834, Mr. Hamilton experienced a most severe shock, in which the movements of the earth were entirely vertical, and seemed to take place twice every second. He mentions also, the terrible earthquake on the coast of Chile, the 5th of February, 1835, by which the sea-port of Concepcion, and Talcahuano, the capital of the province, were totally destroyed. The sea then retired several times to a great distance, and returned in immense billows. It is believed, that new banks were then thrown up from its bottom, and that it was on one of these that the *Challenger*, ship of war, a few months after, was wrecked.

Mr. Murchison exhibited several new geological maps of different parts of Germany, and specially directed attention to two inedited maps, which had been prepared for the author's use, and which he proposed to avail himself of in subsequent researches. The first of these was a map of parts of Silesia, Moravia, and Bohemia, by Leopold Von Buch; and the second a very large unpublished map of Germany, by M. H. Von Dechen, which he stated to contain a greater mass of important detail as regards geological and mineral distinctions than any map of the present period.

On the Solvent Power exercised by Water at high temperatures on Siliceous Minerals. By Julius Jeffreys.

"The few remarks I have to offer have reference to a paper read before the Royal Society of London last spring. It briefly related an experiment made to determine the action of water, in the form of its vapour, upon siliceous minerals at very intense heat. The experiment was upon a large scale, and consequently very costly, and the results were curious, as establishing a very powerful action by water on siliceous minerals, when the temperature is sufficiently high." Mr. Jeffreys exhibited an enlarged drawing to the Section, showing the construction of a large boiler, erected near Furrukabad, a large city 800 miles north-west of Calcutta. It was the only one of the kind in India, and was employed for vitrifying brown stone ware, the manufacture of which Mr. Jeffreys had succeeded in introducing into that country. It was heated by four exterior furnaces, each six feet long and five wide. The kiln inside was fifteen feet in diameter and twenty-four feet high. The fuel was wood, and the utmost effect any alkali which might be supposed to rise in its vapour ordinarily produced, was a slight glazing of some of the brick surfaces in the kiln, near the entrance of the flame; an appearance which is also seen with other fuel, and with which all manufacturers are familiar. "For the sake of experiment, I pulled down the four furnaces and rebuilt them, after having made between each and the kiln a deep pit as wide as each furnace, and only nine inches from front to back. About three feet of water was put into each pit, and was renewable from without. Some felspathic and siliceous minerals were placed in the way of the current, just inside of the kiln, and upon some of the arches a few articles of ware were placed, that any action upon them might be observed. Below a full red heat little effect was perceived, but at a heat above that of fused cast iron a rapid solution of mineral matter took place. This heat was continued ten hours. When the kiln was opened, more than a hundred weight of mineral matter, though in a very dense and refractory form, had been dissolved, and carried away in the vapour. The wall was eaten away, as shown by the dotted line, and presented a rough, and quite unglazed surface, like loaf-sugar partially melted by water, or as if eroded by some animal; and nothing of the smooth glazed surface, which invariably attends the action of alkali on a siliceous surface. Some articles of ware in the hottest situations were partially eaten through; but on the uppermost arch, where the heat was only a full red, a curious phænomenon appeared. The articles there had received, exterior to their own brown gloss, and loosely encrusting it, a complete frosted coat of silica, having the appearance of a candied surface. It was manifestly a precipitation from the mineral vapour, and in fact a hoar frost of silica. There was probably from half an ounce to an ounce on each vessel, and several pounds altogether were thus precipitated; but by far the greater part of the mineral vapourized was, as might be supposed, carried away in the current. Since this powerful action was apparently entirely due

to the presence of water, there being at all times the same quantity of alkali present in the fuel, whatever that might have amounted to, producing no such effect, the experiment seems to establish, at very high temperatures, a powerful action of water on siliceous matter. To attribute the action to alkali would not lessen the difficulty, both because under perfectly similar circumstances, when there was no water, no effect was produced, and because each pound of alkali would have had to dissolve, perhaps, forty pounds of silica. Mr. Jeffreys was informed by a military engineer of distinguished ability, to whom he related the experiment, that he had once observed a similar destructive effect upon the brick casing of a kiln, by moisture getting in at an intense heat, though no scientific notice was taken of it at the time; and as coal was the fuel in this case, there was still less ground for supposing the action to be alkaline. Lastly, if alkali did play an appreciable part, the experiment would remain still sufficiently curious, as it showed an abundant vapourization of silica, by a fraction of its weight of alkali, without the aid of fluorine, a phænomenon which has, so far as the author is aware, been only obscurely manifested in minute quantities, as noticed by the late Dr. Macculloch.*

An Account of the Construction of the Models of the Island of Achil, Clare Island, and the South-Western district of Mayo, in Ireland. By WILLIAM BALD, *F.R.S.E., M.R.I.A., &c.*

"The chief object of this paper is to call attention to the cultivation of an art hitherto but little practised in Great Britain or Ireland, in representing the irregularities of surface, i. e. the rise and fall of ground in a country by modelling, and also to give an account of some models which I have constructed of parts of the West of Ireland, since 1815.

The first work of this kind I made, was a model of Achil, the largest island on the coast of Ireland; it contains fifty-eight English square miles of lofty ground, and has been deposited in the museum of the College of Edinburgh. The second model made was that of the Barony of Murrisk, containing nearly two hundred square miles, and which occupied me at intervals for a period of nearly five years; it was formed of putty, white-lead and cork.

I also constructed a model of Clare Island, on the west coast of Ireland, an island which is four English miles long, by two and a quarter in its greatest breadth. A cast of this model was deposited, on the 26th of April, 1830, in the French National Institute, and another one in the model department of the Bibliothèque du Roi, at Paris, and were on a scale of eight inches to the Irish mile; but the models of Achil Island and Murrisk Barony were on scales of four inches to the

* Professor Johnston and Mr. Jeffreys have been requested to prosecute researches on this subject.

English mile. The perpendicular scales, or those of height and depth, were the same as the horizontal."

The author thus describes his method of modelling: "I drew out upon the smooth surface of a prepared board, made of deal-timber, an exact outline of the coast, lakes, rivers, roads, &c., &c., of the district to be modelled; and the different heights taken by the level, theodolite, sextant, and barometer, were correctly marked upon the board in their exact positions, by driving down small iron pins, the summits of which indicate the elevations, measuring the heights from the surface of the board as the level of the sea, at ordinary high water spring-tides; and all the spaces between the respective heights marked out by the iron wires were filled up with the putty; but where the elevations were considerable, cork, cut into thin pieces, was used in combination with it, so as to give firmness, and prevent sinking, which would have been the case if large quantities of putty were used without adopting this precaution.

The lakes are represented by different pieces of painted glass, the outlines of which were first traced upon the painted sides, which appeared like a fine hair line through them when laid in their positions, and the putty was wrought forward over the edges of the glass to the outlines of the lakes so traced out, but it was always necessary to keep the putty from touching any part of the painted glass underneath, for if it did the oil of the putty soon disfigured the water colour of the lakes.

The model of Murrisk, containing, as before mentioned, nearly two hundred square miles, was formed of putty and white-lead; the poisonous qualities of which nearly destroyed my health, and I mention this circumstance as a caution to those who may hereafter be engaged in similar works.

I found it extremely difficult to model in putty; and again much more so when combined with white-lead. What I found best and most easy to work with was pipe-clay, but then, when it dried, it always split into pieces. The best substance to construct or form models with is large blocks of chalk, closely joined together, and then to carve out the various forms of hill and vale; and when finished, to shade the surface over several times with prepared linseed-oil, by which means it will become highly indurated.

The composition used by General Pfeffer for modelling was a mixture of charcoal, lime, clay, a little pitch, and a thin coat of wax."

To the communication from which the above extracts are taken, Mr Bald appended a notice of the rise of Topographic Maps.

ZOOLOGY AND BOTANY.

On the true Method of discovering the Natural System in Zoology and Botany. By Hugh E. Strickland, *F.G.S.*

The object of this essay is to show that the true system of nature is not to be discovered by any *à priori* or theoretical considerations, but solely by an inductive process similar to a geographical survey. Assuming the reality and permanence of species, the natural system is defined to be, the arrangement of species according to the degree of their mutual resemblances. *These degrees of resemblance* are to be estimated by the physiological importance of the points of agreement, combined with their numerical amount in the objects compared. It is these essential and important points of agreement which constitute *affinity* as distinguished from *analogy*. The method proposed is to take any one species A, and ask the question, "What are its nearest affinities?" Those other species (whether one or many) which are closely and equally allied to A, are then to be placed on each side of it. We are then to take one of these latter species and ask the same question. By a repetition of this process it would be possible ultimately to survey and construct a map of the whole organic creation. And as in a map the physical surface of the ground is divided for convenience sake into provinces and kingdoms, so may the species when so arranged in their true position be divided into families, genera and groups, which may themselves be mapped in the same manner as species.

In following out this plan it will be found that species or groups do not form a continuous or linear series, but frequently ramify in various directions. It will be further found that they do not ramify according to any regular figure or numerical property, but resemble rather the irregular branches of a tree. The *irregularity* of the details of the natural system is maintained in this paper, and it is inferred that we are consequently unable to predict what species or groups may yet remain undiscovered. If this be true it follows that all those systems, whether linear, circular, quinary, or otherwise, which follow a symmetrical and regular figure, must be, not natural, but artificial. Such systems possess certain practical advantages in the arrangement of museums, &c., which are incompatible with the inherent irregularity of the natural system; but the latter is not on that account to be disregarded or confounded with the artificial systems above alluded to.

In further proof of the amorphous and unsymmetrical figure of the natural system, it is shown,

1st. That the analogies of the external world, such as the positions of the fixed stars, the distances of the planets, the forms of mountains, rivers and islands, &c., indicate that amorphous variety, and not geometrical or numerical symmetry, is the prevailing law of nature.

2nd. That as organic structures are created not for the purpose of being classed in museums, but for the discharge of certain offices

in the external world, it follows, that if the conditions of existence, such as soil, climate, locality, &c. be indefinitely various, the forms of animals and plants which are adapted to those conditions must be indefinitely various also. Perfect symmetry would only be compatible with the natural system on the supposition that all the variations of the earth's surface, the mountains, rivers, islands, soils, currents and winds were absolutely symmetrical in their situations and regular in their influences.

On the Development of the Fish in the Egg. By Professor AGASSIZ.

Professor Agassiz gave an account of his researches on the development of the embryo in the ova of fishes, more especially of the family of Salmonidæ. He detailed at great length the successive changes undergone by the various systems of organs. The object he had in view in these investigations was to ascertain if there existed any relation between the forms of fish of the present day, during the successive stages of their development, and the permanent forms of fish found in the older strata of the earth.

On the First Changes consequent on Fecundation in the Mammiferous Ovum, with special reference to a Communication "On the Development of the Fish in the Egg," by Professor Agassiz. By. Dr. MARTIN BARRY, *F.R.S.*

The remarks were intended as an outline of a memoir, communicated by Dr. Barry to the Royal Society of London in March last. The memoir itself being now in the course of publication in the Transactions of that Society, Dr. Barry stated that he could not, with propriety, anticipate its appearance by further details than had been already published, as an abstract, in the Society's "Proceedings." He had had no intention indeed of offering a paper on the subject to the British Association until yesterday, when a communication was made by the celebrated naturalist of Neufchatel, which called for some remarks at his hands.

Nearly every author on the ovum allows the germinal vesicle to be its most essential part. The office which this vesicle performs, however, and its destination, had been subjects of speculation only. Purkinje, the discoverer of this vesicle where it was first found, namely, in the bird's egg, supposed it to burst; and either the same opinion, or else that it dissolves, flattens down, or becomes otherwise destroyed, had been conjectured by most subsequent observers. All, however, including the eminent naturalist whose observations Dr. Barry had now more particularly in view, Professor Agassiz, were agreed that the germinal vesicle disappears about the period when the ovum leaves the ovary. The question is, its mode of disappearance.

Dr. Barry then read, from the Royal Society's "Proceedings," a portion of the abstract above referred to, from which it appeared, that should the statements there made be confirmed, this very important question had at length been solved by actual observation. We refer to the abstract itself for an account of the remarkable results obtained, from which also it appears that the centre of the germinal spot is the point of fecundation, and the place of origin of two cells which constitute the foundation of the new being; results, however, which if confirmed, must modify the views recently advanced on the mode of origin, the nature, the properties, and the destination of the nucleus in the physiology of cells.

Dr. Barry's observations were made on ova of the rabbit; and he afterwards confirmed them by an examination of ova of the dog. He had stated that the ova of birds, batrachian reptiles, and some osseous fishes, afford evidence of the operation of the same process: and it was very gratifying and important now to find, in the minute and beautiful delineations of such an observer as Agassiz, on the ovum of the salmon, what he (Dr. B.) could not but regard as a confirmation of his own observations on the ovum of Mammalia; though that observer would hear with surprise the explanation Dr. B. was giving of them.

But such a process is not limited to the Vertebrata. It was to be recognized in the description given by authors of certain of the Mollusca; for instance, in that of Sars, on the development of the ovum of Tritonia, Doris, and others of this class of animals. What Sars supposes to be transformations of the *yelk*, however, will no doubt turn out to be successive generations of cells, the first pair of which arises within the germinal vesicle, as in the ovum of Mammalia. Shuttleworth had discovered that red snow contains animal structures; and two days since, Professor Agassiz, having extended this observation, made known the very interesting fact, that the so-called *Protococcus nivalis* consists of the ova of one of the Infusoria. Dr. Barry had now to mention, that while the drawings, which the Professor had given of these ova, were circulating among the members of the Section in that room, he had recognized in them traces of what seemed to him to have resulted from essentially the same changes as those in the germinal vesicle elsewhere. Further, the germ of certain plants passes through states so much resembling those occurring in the germ of mammiferous animals, that it is not easy to consider them as resulting either from a different fundamental form, or from a process of development, which even in its details is not the same. In the growth, indeed, at all periods, and this both of healthy and of morbid tissues, there is to be recognized the same process, which consists, not merely in the origin of cells in cells, but in the origin of cells in the central part of what had been the nucleus of cells.

In a paper published in the "Philosophical Transactions," Part II., 1839, Dr. Barry had shown that the mammiferous embryo is no part of a so-called blastoderma, but the metamorphosed nucleus of a cell.

On the Alpaca. By Mr. W. Danson.

Since the meeting at Birmingham, about thirty of these interesting animals had at different times been imported into Liverpool, and upon the present occasion four of the animals were exhibited in the court-yard of the college at Glasgow, and others at the neighbouring Zoological Gardens. The Alpaca is remarkable for having extraordinary long wool, samples of which were shown, the staples measuring from twenty to twenty-four inches in length, and of various colours, some pure white, that take good dyes. This wool is naturally free from grease, in which respect it differs materially from that of the sheep, a circumstance attributable to its not perspiring through the skin, and consequently not requiring the artificial protection of smearing with tar and other substances, injurious to the wool as far as the manufacturer is concerned; and in the shearing the animal requires no washing preparatory to that operation.

Mr. Danson particularly pointed out the hardy character of the Alpaca from the circumstance of its flourishing immediately under the line of perpetual snow in the mountains of the Andes (Peru); and a not less singular or valuable fact, that of their peculiar coat of silky wool, proving a complete protection against an atmosphere at all times excessively humid, and against the deluging rain that continues to fall upwards of four months in the year, rendering them, in his opinion, well suited to the Grampian, and other mountainous districts of Scotland.

The animal is not only capable of undergoing great fatigue, but likewise of living on mountain herbage, little better than withered grass, and in times of scarcity has been sustained several days without water, taking only a handful of maize. The flesh is considered equal to venison, being commonly eaten by the Peruvians, who state the slaughter of the animals for food to be equal to four millions annually. The importations of the Alpaca wool, Mr. Danson states to be in 1839 one million pounds, and within the last year to have increased to three millions.

On the Subject of a Paper on the Structure of Whales, read at the Birmingham Meeting. By G. T. Fox, *Esq.*

The Section of Natural History were informed that the letter stated to have been written by the Bishop of Durham*, was a fabrication of the individual from whom Mr. Fox had received it as a genuine document, and that no such original letter exists.

On the Structure of Fishes, so far as the analogies can be traced between the Limbs of the Mammals and the Fins of Fishes. By Dr. Macdonald, *F.R.S.E., &c.*

It has hitherto been generally considered that the pectoral fin of the fish is the analogue of the wing of the bird, or anterior extremity of

* See Reports of Association for 1839, p. 89.

man and higher Mammals, and that the ventral fins are the analogues of the pelvis and posterior extremities. The error of this opinion it is the object of this communication to point out.

Tabular view of the names of the several parts of the skeleton of fishes analogous to the limbs of higher Vertebrals.

Dr. Macdonald.	Ichthyological Names.	Cuvier.	St. Hilaire.
Scapulo-clavicular arch.	*Opercular Bones.*	Pre-opercular bones.	
Arm or Wing		Opercular.	Stapes.
Fore-arm.		Inter-opercular.	Malleus.
Hand.		Sub-opercular.	Orbiculare.
Pelvis	PECTORAL FIN.	Scapula, or Supra-scapula.	
Femur		Scapula.	
Fibula		Coracoid.	
Tibia		Clavicle and humerus.	
Tarsus	*Fin-rays.*	Radius.	
		Ulnar.	
		Carpus.	
		Metacarpus.	
		Phalanges.	
Belonging to the external skeleton.	VENTRAL FIN.	Pelvis.	
		Femur.	
		Fibula.	
Pubis, or the cartilaginous extremities of the laminæ.		Tibia.	
		Patella	
		Tarsus (7 bones).	
		Metatarsus.	
		Phalanges.	

By referring to the table, it will be seen that Geoffroy St. Hilaire proposed the opercular bones as the analogues of the bones of the internal ear in a very expanded state. This theory, however, was scarcely tenable, and was never generally received. The author showed that, viewing the whole animal on a zoological scale, or even restricting the survey to the class of fishes alone, it will be more in accordance with analogy of structure and function to consider, that in the osseous fishes the opercular bones are the analogues of the shoulder and arm, which, in the cartilaginous rays are found so greatly enlarged and developed as to form nearly the whole body, acting like wings, as organs of motion. In the skeleton of the *Lophius Piscatorius*, exhibited through the kindness of the venerable Professor Jeffrey, it will be seen that there is a set of fin-rays attached to the opercular bones; but as these are only developed in the substance of the skin, and have never protruded beyond the surface, this fin has never been noticed by systematisers and naturalists, who disregarding characters established on organic structure, are satisfied with the useful, but more superficial characters of fin, scale, or feather.

The constant connexion between the anterior extremity and the respiratory organs assists in tracing the analogies; and when the organ of motion is provided by the tail, as in osseous fishes, then the *usual*

limbs are restricted to assist the function of respiration, which is branchial in fishes and amphibia in their earlier life; but when the pulmonic system is found in air-breathing animals, the respiratory limb is more fully developed, for the purpose of locomotion; and where both systems of respiration by lungs and gills exist, as is seen in the Proteus, we find both the opercular arch and the scapulo-clavicular arch having a limb attached, as the plates of the Axolotl, published in the work of the illustrious Humboldt, clearly exhibit.

In regard to the pectoral fin, an examination of the table will show a more equally balanced accordance with the parts of the limb in the higher Vertebrals, in the analogies proposed in this communication, than in those of Cuvier, where two bones of different laminæ are called parts of one bone; and on the other hand, one bone is called on to represent two belonging to different laminæ. The beautiful articular joint between the pelvis and femur (such as is never found with scapula, even when that bone exists in two pieces, as in the ribless frogs), first showed the key to the explanation; and being on the inner aspect of the pelvis, the leg has been turned with the fibula (or coracoid bone of Cuvier) on the inside, and the largely developed malleolus of the tibia on the outside, meeting on the mesial line below the respiratory organs. This change of the limb will cause the sole of the foot to be placed anteriorly; and we find that the most common action is to balance the animal, and enable it to back out, while the whole progressive motion in the osseous fishes is produced by the tail. The arrangement of the tarsal bones, in man, resembles very much that of the arm and fore-arm, and in fishes has tended to the mistaking the tarsus for the whole anterior extremity.

A very opposite system was obtained in the case of the ventral fins, where one bone on each side support the fin-rays; these bones seem the analogues of the cartilages of the ribs or pubis of the Vertebrals, or perhaps the additional limbs on the ventral rings of the Crustaceæ; here one bone on each side represents the two circles or laminæ entirely.

The author therefore considers that the anterior extremities of higher Vertebrals have their analogues in the opercular bones of osseous fishes; and the analogue of the posterior extremities is to be found in the pectoral fins of the same class.

On the Salmon Fry. By James Wilson, *F.R.S.E.*

The author laid before the Section a series of specimens of salmon fry, with a view to illustrate Mr. Shaw's recent discoveries regarding the early condition of that important species. It was the inspection of that series which first convinced Mr. W. of the accuracy of Mr. Shaw's views, and he felt anxious that those who might still entertain any doubts upon the subject should have an opportunity of removing those doubts by the examination of a suite of specimens prepared by that ingenious observer. The prevailing opinion upon the

subject had previously been, that young salmon hatched in the spring of any given season made their migration to the sea in the course of that same spring, that is, when they were only a few weeks old, and that they consequently bore no relationship to that other small fish commonly called the parr, which was known to inhabit our river waters during all seasons of the year. Mr. Shaw, however, has proved that both those views are erroneous, and that the fry continue for about two years in the river, during which they are actually the parr, and are converted in the course of the second ensuing spring into smelts or young salmon, as usually recognized. The specimens exhibited by Mr. Wilson demonstrated the occurrence of that change.

On the Organs of Sense in the Salmon. By Dr. LIZARS.

After demonstrating the structure of the skin, the author showed that the colour of the animal depended not merely on the rete mucosum, as in the dark varieties of the human race, but that the superficial fascia exerted a great influence, from its colour and the transparency of the dermis. The rete mucosum was a soft gelatinous layer, presenting a number of minute black points, which were very abundant in the dark, but few in the light parts of the skin. The superficial fascia bore the closest resemblance to the rete in the greater part of its extent; but in some situations it exhibited the appearance of adipose tissue. From the arrangement of the nerves, the skin appears far from being highly organized for the function of touch. The same remark applies to the tongue and the sense of taste; first, from the state of the mucous membrane, and second, from the small size of the gustatory nerves. The organ of smell was very highly developed. It is contained in an elongated cavity placed in the upper and fore part of each side of the head, leading to each of which there are two apertures placed close together, the septum between them serving the purpose of a valve to the anterior, so that water could enter, but could not escape by it. Upon examining the posterior opening with the microscope and with bright sunshine, a number of minute white filaments, bifurcated at their extremity, were observed: they were supposed to be ciliæ; one or other of their minute extremities was seen bending and extending itself. On the inner wall of the cavity were twelve delicate folds of membrane, attached to a slight prominence, and receiving the filaments of the nerve of smell. He supposed the water, loaded with the odoriferous particles, to enter by the anterior orifice, flow between the olfactory folds, impress the nerve, and escape by the posterior aperture; the ciliæ in the last producing the current in that direction. In the description of the eye, a peculiar thickening of the cornea was pointed out a short way from the circumference, and more extensive at the lower than at the upper part. The sclerotic coat he found very thin, single, and having a thick, strong layer of cartilage extending from near the cornea to within three or four lines of the optic nerve. The ciliary ligament is very soft and delicate. The

appearance of an outer and an inner circle in the iris was seen, but no muscular fibres: the delicate membrane described by Jacob on the posterior surface of that body, he found to be reflected from its external circumference to the fore part of the hyaloid membrane, which it accompanied to the capsule of the lens. The choroid membrane, single in front, is double posteriorly, inclosing between its layers the choroid body, which was supposed tó consist of erectile tissue, and to enable the eye to adjust itself to vision at different distances. The ciliary processes are wanting. The retina extends from the optic nerve to where the choroid membrane forms a continuity with the iris. The humours are similar to those of other fishes; and in examining the fibres of the lens with the microscope, the serrated appearance described by Sir David Brewster was seen. The organ of hearing consists of a lower and upper sac, and three semicircular tubes; the sacs are lodged in the interior of the skull, and the tubes connected with the upper, in canals formed partly of bone and partly of cartilage. The interior is filled with fluid, and in each sac there is a dense calcareous mass or otolite; that in the upper being small and round, that in the lower large and triangular. The auditory nerve divides into a number of branches distributed to the sacs and canals.

On the various Modes of Fishing employed by Indians in the West of Guiana. By M. Schomburgk.

Although the Ichthyology of South America be little understood by European naturalists, yet the native Indians are practically well acquainted with the various tribes that are found in the magnificent streams of the New World. An acquaintance with about eighty species has thus been made by M. Schomburgk. The Indians in their fishing excursions use canoes, which are propelled and directed by paddles in a peculiar manner. The canoes on the Essequibo are mostly formed of a hollow tree, and small corials are used formed in the same manner. Another kind of boat is also used, called a pakasse, and formed out of the bark of a tree. "When we ascended the river Berbice," says the author, "two Wauawai boys belonging to our party navigated one of those pakasses. They we're perhaps not more than eight years old, but we were highly delighted to see how ably they managed it. The boat seemed to fly through the water, and the juvenile steersman directed its course with such judgment and precision that it never grounded, though it went over places where there were not more than eight or nine inches of water. They were equally expert in the use of the bow and arrow; and, wherever they observed one of the finny tribe, the pakasse was halted, the bow strung, and off flew the pointed arrow, and when taken out of the sand, which the water barely covered, we generally observed a fish struggling for liberty." After describing the descent of the rapids, in which these rivers abound, and the appearance of a band of travellers halting on the shores of the river, he adds, "During night commenced the fishing

of lan-lan and others of the family Siluridæ. After the hooks have been baited with fish or animal flesh, they are carried out in the stream; the line to which they are attached being about thirty to forty fathoms long. If the Indian feels inclined, he keeps the end on the land in his hand, but frequently he takes a forked stick, which he drives into the ground, and, after having tied some dried bushes to the fork, he leads the stray line over it. If a fish should bite, the line being drawn by the baited fish, will disturb the dry leaves, make a noise, and the Indian hurries to seize the line and to haul the fish in. If it be a lan-lan (*Silurus*) or a large paramima (*Phractocephalus bicolor*), some considerable skill is necessary to haul the fish in without breaking the line or the hook. Many of the Siluridæ issue a sound when taken out of the water, but few so loud and so continued as the paramima. The Indians have always a bludgeon in hand, with which they beat in the thickly armed skull, and each blow is sure to produce a loud grinding sound; so that we who were lying in our hammocks knew whether a lan-lan, paramima, or any other fish had been secured. The Indian considers that a large fire kindled at the water's edge is sure to attract such fishes as take the bait only during night, and they never fail, therefore, to have a fire or a large brand when they are fishing for lan-lans or paramimas. If large blocks of granite impeded the river near our corials, all hand-lines which could be spared or procured were set in requisition to fish for pirais (Serra-salmon). The avidity with which they take the bait ensures success to the least practised, and if the place proved a haunt of the pirai, the Indian was sure to secure his dinner. The natives possess great art in throwing the hand-line from the shore into the stream; and it is a pretty sight to see the line circling in the air and descending into the water at a great distance from the bank or rock which the angler has selected for his stand." The detail of other modes of fishing was also entered into, and drawings of the paddles, hooks, rods, lines, and instruments used in fishing were exhibited.

Mr. Smith, of Deanston, exhibited a model and gave a description of a Salmon Stair. The object of this construction was to allow of the passage of salmon up streams where mills or other impediments existed. After various efforts, Mr. Smith succeeded in erecting one near his own residence, which answered the purpose. The salmon, by means of a dyke constructed by the side of the mill-stream, were enabled to pass up the stream, whilst a wire defence kept them from falling into the mill-stream.

On some Persian Insects. *By* JAMES WILSON, *F.R.S.E.*

The author exhibited to the Section a small collection of insects from Persia, which he presumed would interest those members who devote themselves to entomology, as so few entomological products had ever been transmitted from that part of Asia. These insects

were collected chiefly in a district of Persia, about thirty miles N.E. of Tabriz, and were transmitted by Mr. Robertson, a Scotch gentleman, employed by the late Shah in the capacity of mining engineer. Mr. Wilson observed, that the interest of this collection arose from two sources; first, from the occurrence of several singular forms of new and rare species; and secondly, from the occurrence of many species well known in the southern and eastern portions of Europe, but with the progress of which, in a still more southerly direction, we had been hitherto unacquainted. Mr. W. had always been of opinion that the elucidation or completion of the history of previously known species was equally interesting and important as the discovery of new species, and he regarded the occurrence in this collection of so many of the insects of southern Europe as a valuable fact in the history of those species. Several African insects may also be observed, such as the *Ateuchus sacer*, or sacred beetle of the Egyptians, a species so often found sculptured on the symbolical monuments of that nation. On the whole, however, so far as can be judged from this collection, the aspect and character of Persian entomology seem to present a strong affinity to that of the southern parts of Europe.

A letter was received from M. J. F. Brandt, Director of the Zoological Museum of St. Petersburgh, accompanying printed extracts and notices of his recent zoological labours. In this communication, M. Brandt notices that his investigations in Myriapoda lead him to rank them as an order of the class of insects, and not as an independent class of animals, and to divide them into mandibulate and suctorial tribes. Of the genus *Iulus* of Linnæus, M. Brandt has arranged in the Museum of the Academy of St. Petersburgh forty species; he notices the middle part of the lower labium as affording excellent characters for specific, subgeneric, or even generic distinctions; the joints of the antennæ, the hind margin of the penultimate body-ring, the oval scale, the pediferous laminæ, also afford useful aid, and in the specific distinctions the first dorsal ring is not to be disregarded.

M. Brandt is especially desirous of obtaining specimens of British Myriapoda for comparison, and in exchange for the Russian species. Being also engaged in the study of the group of Cormorants (Carbo), he requests similar aid from members of the Natural History Section of the British Association in respect to this group of birds.

Mr. Adair exhibited specimens of *Patella ancyloides* found on the coast of Arran.

On Pelonaia, a new genus of Ascidian Mollusca. By JOHN GOODSIR *and* E. FORBES, *F.L.S.*

The authors have lately met with two undescribed marine animals, which are referable to a new genus of Ascidians. One of these was

found in the mud-filled cavity of a dead bivalve, from thirty fathoms water, in the Frith of Forth; two specimens of the other were dredged near Rothsay.

The appearance of these animals was so peculiar, that the authors were unable to determine their position in the system, till anatomical examination displayed their relation to the Tunicata, and revealed the interesting character of the genus to which they belong.

The animals of this genus are free, elongated, dilated posteriorly, with the respiratory and excretory orifices approximated, the first being at the anterior end, in the axis of the animal.

As both the species were found in muddy ground, the genus is named ***Pelonaia*** (πηλος ναιω).

The Frith of Forth species, *P. corrugata*, is characterized by transverse, somewhat irregular rugæ; dark brown; length $2\frac{1}{2}$ inches.

The other species, *P. glabra*, smooth, with slight villosity; grayish-white; length 1 inch.

The author found the two species to possess the general structure of the other Ascidians. The peculiarities were—1. The respiratory opening has no radiated folds or papillary fringes. 2. The respiratory sac is elongated, median, exhibits transverse folds, which contain the primary branches of the branchial artery and vein, and are tied to the internal surface of the muscular sac, and to the reproductive tubes, by a longitudinal row of thread-like bands on each side. It gradually contracts posteriorly into the œsophagus. 3. The digestive tube floats free in the capacious cavity of the muscular sac, except where it is tied down by vascular bands, and it terminates in free, floating, and radiating extremities in the interior, and half the length of the animal from the excretory opening of the sac just mentioned. 4. The vascular system exhibits no heart; and in consequence of the peculiar relative position of the respiratory sac and the other viscera, the system is symmetrical, the blood flowing backwards in the branchial vein and systemic artery, and forwards in the systemic vein and branchial artery, these two systems forming a dorsal and ventral trunk. 5. The reproductive organs consist of two elongated tubes, shut at one extremity, opening at the other into the cavity of the muscular sac, and closely attached to its inner surface. The orifices of these tubes are situated at the anterior third of the animal, and one-third of the posterior extremity of each is turned inward and forward, so as to become parallel to the rest of the tubes and to the branchial artery. Along the whole length of these tubes, close-set parallel cæca open into their cavities, a simple form, in fact, of the more complicated reproductive organs in the other Ascidian genera. 6. The principal peculiarity of the muscular cloak is firm adhesion to the whole internal surface of the tunic. In consequence also of the attachment of the viscera to its internal surface along the lateral lines only, its cavity is made more capacious, resembling, in this respect, the water-filled cavity of certain Echinodermata. A strong band is situated just behind the excretory orifices.

From what has now been stated, it appears that external and internal

symmetry is the leading peculiarity of *Pelonaia*. It is this symmetry which renders the genus valuable to the comparative anatomist, as it reveals to him the relations of the different organs in the unsymmetrical Ascidians, and enables him to refer each of the former to its proper position in the series of organs in the animal kingdom. He is now enabled to state, with certainty, that the branchial vein, heart, and systemic artery of the typical Ascidians correspond to the dorsal vascular system of the annulose animals, and the systemic veins and branchial artery to the ventral vascular system in some of the latter. The annulated respiratory sac, and its lateral longitudinal attachment to the parietes of the body and to the symmetrical reproductive organs, the ventral position of the nervous centre, and excretory opening, all point to the same conclusion. The genus is equally valuable to the systematic naturalist, as it indicates the relations of the Mollusks to the annulose animals on the one hand, and to the Echinodermata on the other.

On the Regeneration of Lost Organs discharging the Functions of the Head and Viscera, by the Holothuria and Amphitrite, two Marine Animals. By Sir JOHN G. DALYELL.

The adult Holothuria resembles a cucumber, or a sausage, from six to twelve inches long, purple, yellow, gray or white. Some thousand suckers cover it like a shaggy coat, or disposed in rows according to species, affixing it firmly to solid substances, where it remains quiescent in a crescent form during the day; but when evening comes, a tuft, protruding from the larger extremity of the crescent, unfolds into a capacious funnel, composed of eight, or ten, or twenty beautiful branches, implanted on a shelly cylinder, in the centre of which is the mouth. Each branch now begins to sweep the water in succession, and descends almost to the root within the mouth, in a contracted state, whence it arises to enlarge anew. These evolutions are protracted until the latest hour; but as morning dawns, the whole apparatus is withdrawn, the skin close and compact as before, and a fountain begins to play from the opposite extremity. This singular animal is liable to lose all the preceding organic apparatus, consisting in the *Holothuria fusus* of eight longer and two smaller branches (tentacula), together with the cylinder, mouth, œsophagus, lower intestinal parts, and the ovarium separating from within, and leaving the body almost an empty sac behind; yet it does not perish. In three or four months all the lost parts are regenerated, and a new funnel, composed of new branches, as long as the whole body of the animal, begins to exhibit the same peculiarities as the old one, though longer time be required to attain perfection. Other species of the Holothuria divide spontaneously through the middle, in two or more parts, all becoming perfect ultimately, by the development of new organs. Yet the anatomical structure of the whole genus is so complex as to defy the skill of anatomists in discovering the proper functions of some of the

parts. A single Holothuria has produced 5000 ova in the course of a night. The young resembles a white maggot, when of the size of a barley corn. The animal may lose and regenerate its organs more than once; it is very rarely to be procured entire; nor until the drawings now laid before the Association, has it been ever represented alive and perfect. The specimen survived with Sir John about two years.

The Amphitrite is an animal still more interesting, from the faculties it possesses and the properties which it enjoys. Various species inhabit the Scottish seas, all occupying tubes, either of their own manufacture, by a process truly mechanical, or a thin silken sheath formed by an exudation from the whole body, or they rest amidst a thick tubular mass of transparent jelly, also of animal secretion. The body of the *Amphitrite ventilabrum* extends twelve inches or more in a serpentine form, consisting of 350 segments, crowned by a beautiful varied-coloured plume of eighty or ninety fleshy feathers, and terminated by a double gland. These (the branchiæ) are arranged as a funnel or shuttlecock, three inches deep, and resembling the finest flower, with two spines in the centre, and each feather is bordered by at least 500 ciliæ or fleshy hairs along the shaft. This, which is the most timorous of creatures, dwells in a black leathern-looking perpendicular tube, two feet high, entirely of its own manufacture, rooted by the lower extremity. The observer possesses the ready means of inducing the humble tenant to display its powers. If, while stretching its beautiful plume above the orifice of the tube, and spreading it to enjoy the circumambient element, he drops a little muddy matter from above, an interesting spectacle ensues: immediately all the feathered apparatus is seen in action, though the animal be apparently still. Forty thousand ciliæ are at work, and a mass is soon discovered accumulating at the bottom of the funnel. Being thence transmitted to the mouth, it is imbued with gluten, and discharged as paste on the edge of the orifice of the tube. There the creature having raised itself still higher, performs a slow revolution while moulding the paste into proper form by means of two organic trowels, prolonged from a fringe around the neck. With these it beats down the paste, and clasping over the edge of the tube, smooths its materials into symmetry, as if it were by the operation of human hands; but on the slightest alarm the plume collapses, the artist sinks below in an instant, and remains with the orifice closed, until believing the danger over, it may rise to resume its task in security. As specimens occur of all different dimensions, let the observer cut a fragment off the lower end of the tube, which is always longer than the tenant; it will be affixed again where desired. Treating a number thus, and tossing them into a glass jar of sea water, a grove will arise before him from the animals fixing them anew, and protruding like so many revolving flowers to collect muddy drops from above, with which he provides them. The adhesion is accomplished from a glutinous or silky sheath, which the double terminal gland seems instrumental in producing. Should the Amphitrite be mutilated of the anterior part, the whole will

be regenerated; nay, should a fragment of the smaller or posterior extremity be sundered from the body, an entire plume, spines, mouth and trowels will be generated to crown the anterior part of this fragment, and render it a perfect animal. It is very remarkable that the powerful reproductive property of the genus is not confined to the vicinity of the lost organs, the elements of others reside in different and distant parts of the body, from whence human perception cannot discover any likelihood of their evolution by means of their own energies. The adult *Amphitrite bombyx*, which obtains a silken sheath merely by spontaneous exudation from the body, is about three inches long, of which a third part is the plume, consisting of sixty or seventy feathers (branchiæ). Two artificial sections of the body, of a vigorous specimen, speedily invested themselves with a sheath, wherein they reposed quiescent. The organization of the upper portion remained in its original state; the middle section acquired the wanting parts, and a plume of eight feathers was generated by the lower section, though this section had been only two lines, or the sixth part of an inch in length. Thus three plumes existed at once, with all their appurtenances, on what had been a single animal. Young animals have few branchiæ; their number augments with age; and both these and the number of segments in all the *Annelides* seem indefinite. In all their ciliated branchiæ, likewise, the rib or shaft is originally bare, and clothed with the ciliæ developing successively upwards.

The paper was illustrated by numerous drawings of living specimens.

Further Researches on the British Ciliograda. By Edward Forbes *and* John Goodsir.

Since the last meeting of the British Association, the authors have continued their observations on these animals; no additional species have been discovered, but several interesting facts, elucidating their structure, have been brought to light. The species examined were the two forms of Cydippe, designated *C. pileus*, and *C. Flemingii*. They have repeated the observations of Mr. Garner on the ciliation of the walls of the stomach and vessels, and can bear testimony to their accuracy. The ciliæ toward the base of the stomach are larger than those on the oval portion. A row of very minute ciliæ surrounds the mouth, but none of these organs are seen on the filamentary tentacula, or on the walls of the filamentary cavities. The ciliæ which are placed on the longitudinal ridges are linear-lanceolate in form, flat, and not hollow. They are not webbed together, and have no communication with the vessels which run beneath the ciliary ridges. Each row of ciliæ is mounted on a transverse base of a more solid texture, and less transparent than the rest of the body. The substance of this base consists of globules irregularly imbedded in a homogeneous substance. A similar structure is seen to exist in the filaments of the Cydippe, and the bodies of the hydroid zoophytes and of the simpler trematoid worms are composed of a like substance. When one of the ciliæ of a

Cydippe is cut off, it has of itself no power of motion, but if the smallest portion of the substance of its base remain attached, it moves with great vivacity. Hence the observers conclude that the ciliary motion is effected by undulatory movements of this peculiar tissue, which explanation will also account for the rotatory appearance of the circles of ciliæ on certain animalcules, and on a remarkable apparatus which they have discovered in the breathing sacs of the *Echiurus*, a vermigrade Echinodermatous animal, allied to the *Sipunculus*. They reject altogether the explanation of the ciliary motions given by Professor Ehrenberg, Dr. Grant, and M. Raspail. From observations made on the circulating system of the Beroideæ, they are led to conclude that the usual definition of that tribe, as acalephous animals having two openings to their intestinal canal, the one anterior and the other posterior, is incorrect. They believe the supposed anus to be imperforate, and a great portion of the supposed intestinal canal to belong to the circulating system.

The tongue-shaped organ which Mr. Forbes formerly described as existing in the stomachs of many of the Cydippes, has proved to be a remarkable parasite trematoid worm, fixing itself by means of four suckers or mouths to the walls of the stomach, and of the vessels of the Cydippe, often interrupting the circulation of its fluids. For this strange parasite Mr. Forbes has constituted a new genus, and designated it *Tetrastoma Playfairei*, in honour of Major Playfair of St. Andrews, who first drew attention to its parasitic nature. The authors summed up their paper by stating the results:—1st. That ciliary motion was effected in the Ciliograda by means of a granular tissue, similar to that forming the bodies of the Hydroidæ and the lower Entozoa, on which the ciliæ are placed: 2nd. That the Ciliograda are not Acalepha, having two openings to their digestive canal (as has hitherto been stated), but similar in structure to the other Medusæ: and 3rd. The discovery of parasites infesting the Acalepha.

On Medusæ. By R. PATTERSON, *F.L.S.*

After briefly noticing some of the specific distinctions of two species of Medusæ common on the Irish coast (*Cyanea Lamarckii* and *Aurelia aurita*), Mr. Patterson stated, that his object in bringing forward the present communication was, principally to direct the attention of the members to the Acalepha of the British shores, a portion of our Fauna hitherto uninvestigated. With this view he described at some length their habits and appearance. He next proceeded to detail some of their peculiarities of organization, especially the difference observable in their filamentary appendages, and the varying number of the mouths and arms. Our ignorance of their physiology was exemplified by a series of questions relative to the organs of sensation which they possess, and the origin and uses of their luminosity, their stinging powers, their means of defence and propagation, their length of life, and their peculiar parasites.

It was stated that we are ignorant not only of the structure of the Acalepha, but even of the species which frequent our shores; an ignorance arising from the necessity of studying these animals in a living state, and also from the want of proper descriptions and figures. Those which may be confided in, are given by Müller, Sars, Mertens, and Eschscholtz, in comparatively scarce works; and as two are written in German, and one in Danish, they are sealed books to those who are ignorant of these languages. In consequence, we are in continual danger, if we venture to name one that appears unknown, of adding to the existing confusion. He next proceeded to mention the points of interest presented by the Acalepha, in consequence of their analogies in several respects, both to other classes of animals and to the corolla of phænogamous plants.

On Animals found in Red Snow. By Professor Agassiz.

It was stated that our countryman Shuttleworth had lately demonstrated that beside the *Protococcus nivalis*, the red snow contained several species of Infusoria. He had, however, now to lay before the Section the result of his own observations, from which he had come to the conclusion that the red snow was altogether an animal production, and that the so-called *Protococcus nivalis* was the ova of a species of rotiferous animal called by Ehrenberg *Philodina roseola*. This animalcule he had found dead in the red snow, and occurring abundantly in ditches in the neighbourhood, at the bottom of which its ova produced a red deposit. Under the microscope the coloured ova in the ovaries could be distinctly seen. He had also seen the Infusoria described by Shuttleworth. Drawings of the *Philodina roseola*, and the other animalcula of the red snow, were exhibited to the Section. The Professor also announced the discovery of a new species of Podura in the clefts of the glaciers of the Alps. Specimens and drawings of this insect were also exhibited.

Dr. Lankester exhibited some coloured water brought from the Baltic by Mr. Murchison. The colouring matter consisted of a filamentous, unarticulated, probably not vegetable, but animal substance. The sea was covered with filaments for miles in extent, so as to be discoloured, and to appear of a dirty white.

Notice of Plants and Animals found in the Sulphureous Waters of Yorkshire. By Edwin Lankester, *M.D., F.L.S.*

Under the terms glairine, zoogene, baregine, humus-extractive, resin, animal, and vegeto-animal matter, &c., the existence of organic substances in cold and thermal mineral waters has been often referred to, but in most instances the origin of these matters is involved in obscurity. Professor Anglada referred glairine, which he found in sul-

phureous waters, to a chemical origin, whilst Dr. Daubeny, in his Report on Mineral Waters, laid before the British Association at Bristol, maintains that this substance is in all cases an organic production. The existence of organic matter, with a definite form, was first pointed out by Willan, which was examined by Dillwyn, and referred to the vegetable kingdom under the name of *Conferva nivea*. This plant has been recorded as existing in the sulphureous waters of Harrowgate, and has been found by the author in the same kind of water at Askerne in Yorkshire. In its young state it answers to the character of the organic fibres described by Daubeny, and in a more mature state to the plant as described by Dillwyn. This plant is of exceeding rapid growth, appearing in water impregnated with sulphuretted hydrogen after standing for a few hours. It also rapidly decomposes, giving rise to secondary combinations which closely resemble the characters of glairine, as stated by Professor Anglada. In the waters of Harrowgate, another species of Conferva abounds, which, in its structure, resembles the species of *Oscillatoria*; it collects in large quantities around the sides of the wells, and with deposits of inorganic and animal matters form layers of a dark green, white and rose colour. In decomposing, these plants give out a more powerful odour than the water itself, a circumstance which has probably given rise to the opinion that a sulphuret of azote exists in these waters. These plants seem peculiar to sulphureous waters, and probably have their existence determined by the suphuretted hydrogen they contain.

In many places where sulphuretted hydrogen is given out, a deposit is frequently found at the bottom of the waters, varying from a light pink to a deep rose colour. These deposits are sometimes exceedingly abundant throughout a large district around Askerne, where sulphureous springs abound; they are always found in water or sand, impregnated with sulphuretted hydrogen. On an examination being made of these deposits, they were found to be produced by two species of animalcula; one oblong, with from two to ten or twelve stomachs about the $\frac{1}{10000}$th of an inch long, the other having about the same number of stomachs, but much longer than the first, and having the motions of a *Vibrio*. The first resembles the *Astasia hæmatodes* of Ehrenberg, which he describes as having been found in Siberia, producing a blood-coloured deposit at the bottom of a lake, but does not appear to possess a tail, which is a character of the genus *Astasia*. These animalcules live in water artificially impregnated with sulphuretted hydrogen, but do not die immediately in fresh water. The author has never seen them naturally without sulphuretted hydrogen, and in many instances has detected this gas by their presence in places in which it would not have been previously suspected.

On the Pollen and Vegetable Impregnation. By Dr. ALDRIDGE, *of Dublin.*

The author having discovered that nitric and other inorganic and organic acids produced the dehiscence of pollen-grains, in the same

manner as if placed on the natural stigmatic surface, instituted a number of experiments, of which the following are the general results:— 1. The spores of cryptogamic vegetables, which some botanists consider analogous to pollen, do not dehisce under the influence of acids. 2. The pollen of the Grasses is spherical, both when dry and placed in water; with acids it bursts, protruding one long cylindrical mass, which remains afterwards unacted upon by the liquid. 3. The pollen of the Aroideæ, Colchicaceæ, Smilaceæ, Liliaceæ, Commelinaceæ, Butomaceæ, Amaryllidaceæ, Iridaceæ, and Cannæ, are, when dry, oval, and marked with a dark neutral line, but become, when placed in water, more broadly oval or circular, the long diameter remaining the same, and the opake line disappearing, after the addition of acid; the external membrane of the pollen or peripollen dehisces by a chink or suture sufficiently broad to permit the contents or endopollen to escape without any alteration in its form, after which the endopollen remains unacted upon by the liquid. 4. In the Salicineæ, Salicariæ, Leguminosæ, Rosaceæ, Crassulaceæ, Saxifragaceæ, Hypericaceæ, Rutaceæ, Hippocastaneæ, Resedaceæ, and the tribe Helleboreæ of the Ranunculaceæ, the pollen when dry, oval, and marked with a dark central line, becomes, when placed in water, round, or nearly so, the dark line disappearing; and when acted upon by acids, assumes a triangular form, and protrudes at three equidistant points cylindrical or club-shaped masses, very similar at their origin to tubes, and presenting the appearance of being enveloped by a membrane. 5. In the greater number of the remaining Dicotyledons examined, the dry pollen is opake, and either broadly oval or spherical. 6. In the Ericaceæ and Epacridaceæ, the pollen grains, when dry, appear triangular or oval in some instances, triangular or rhombic in others, according to the position in which they are examined. Having ascertained the results of acids on the pollen, the author was induced to examine the stigma, and in every case found that the stigmatic tissue gave indications of an acid re-action upon litmus paper. The next question to be examined was, in what manner is the fertilizing influence of the male organs communicated to the ovule? After quoting the opinions of Amici, Brown, Fritzche, Corda, Treviranus, Brongniart and others, the author came to the conclusion that the *boyau*, or intestine-like protrusion from the pollen grains, was the result of the action of acids upon the fluid which contained the fovilla in the pollen grain; and he inferred this from the fact of this tube, or *boyau*, never being formed when the pollen grain is placed in water, but being constant when the grain is placed in acid. After describing and explaining the anomalous character of the pollen grains in Orchidaceæ, Fumariaceæ, Asclepias, &c., the author presented the following conclusions as the result of his researches:—1. The stigma is invariably acid. 2. It is in consequence of this acidity that the pollen bursts. 3. That by the same means the fluid contents of the pollen become coagulated, enveloping the fovilla, and assuming, according to the method of dehiscence, different and very remarkable forms. The memoir was illustrated by an extensive series of drawings.

On the Growth of Cotton in India. *By Dr.* A. BURN.

Samples were presented of four different kinds of cotton, besides some produced from Egyptian seed, all of which were cultivated last year at Kaira in Gujerat, the object being to show that, in the produce of the cotton plants indigenous to India, great variety existed. The cotton differed in several important points, the chief of which were, the length, colour, softness, dryness, evenness and strength of fibre. These being admitted, together with the fact that all attempts have failed during the last twenty years to introduce successfully the culture of foreign varieties of cotton into India, it was argued, that the grand desideratum, the improvement of the staple, so as to equal American cotton, would best be attained by attention to the selection of indigenous seed, and improving it by cultivation, a point which has hitherto been entirely overlooked or neglected. The Egyptian cotton exhibited was remarkably fine; it had been valued in Glasgow at fifteen pence per pound; of all the specimens it alone had been raised by irrigation. Dr. Burn remarked, that his experience had led him to the conclusion, that without the command of artificial irrigation no great quantity of cotton, superior in staple to Surat, could be produced in the Bombay presidency. The facilities, however, for irrigation in India were very great, and antiquarian research, aided by local tradition, and the scattered remains of tanks and canals, now everywhere observable, demonstratively proved that in former times irrigation was the means by which a vast population subsisted, or were protected from famine, consequent on the capricious failure of the annual monsoon rains. Surat cotton is all cultivated as an annual. The Gorea cotton is a perennial plant; none of it is ever exported to this country, being all consumed in the country.

On the Growth of Cotton. *By Mr.* FELKIN. *Communicated by Dr.* LANKESTER.

The subject of the growth of cotton-wool in British India engaged the attention of this Section last year, Major-General Briggs having then read a paper on the subject. At present, hopes are entertained that the American long-staple wool may be replaced by a long staple from Sea Island seed, to be grown in the Sunderbunds of Bengal, situated at the mouth of the Ganges, a district now jungle, but similar, in respect of its marshy soil and exposure to warmth, moisture and the influences of the sea, to islands on the American coast; which are circumstances that seem from experience to be absolutely necessary to the production of the length, fineness and general quality of the fibre in question. The seed of the plants of that class of Gossypium, known commonly as Sea Island, and picked with extraordinary care, were laid upon the table of the Section, in the hope that members who had the means of giving to an experiment the necessary care, and securing to the plants sufficient warmth, pure air and light, might be disposed to sow a few seeds and report

the results. Pods, grown from this seed in a factory in Manchester, the heat of which varied from 100° to 56° Fahr., unripe, because of insufficient heat and a bad atmosphere, were laid upon the table. They were of good size as compared with those grown in the Sea Islands of the American coast, and if fully ripened the staple would be of great length. These pods were stated to be of twice the size of those of Bengal producing the short staple. The object of the experiment was to ascertain if the length of the staple could be secured *elsewhere* than in the Sea Islands, the other circumstances attending the growth of the plant being made as similar as possible. It was conducted by Thomas Bazley, jun., Esq., Boroughreeve of Salford, an eminent cotton-spinner of Manchester.

The following particulars relating to the course of the experiment, were offered to the notice of the Section. The seed was sown in April 1840; but if sown the preceding winter it might have been better. Transplanted in May. The earth was formed of two-fifths river-sand, two-fifths light soil, one-fifth horse-manure; fifteen inches in depth was found too shallow, and thirty inches is recommended as preferable. This soil was kept in a decidedly moist state by frequent sprinklings of the plants with a solution of one ounce of common salt in a gallon of water. The plants in America are found in the driest season saturated in the morning with dew. The plants in Manchester are five feet high, well spread out; showed in July the usual bright scarlet and yellow-coloured flowers, and became full of pods in August. A number of male and female plants grow together.

Remarks on the Synonyms and Affinities of some South African genera of Plants. By G. A. WALKER ARNOTT, *LL.D.*

The object of these remarks was to prove,—1st. That the *Flacourtia rhamnoides* of Eckl. and Zeyh., and perhaps also of Burchell, was the *Doryalis zizyphoides*, E. M., and approached more to Euphorbiaceæ than to either of the orders with which it has been associated. 2nd. That the genus *Schmiedelia* (or *Ornitrophe*) does exist in South Africa, although omitted from the floras; and that several of Thunberg's and E. Meyer's species of *Rhus* belong to it. 3rd. That *Hippobromus* is also a Sapindaceous genus. 4th. That *Eriudaphne* of N. ab Esenb. is identical with *Phoberos*, Lour. 5th. That *Trimeria* of Harvey has been already but erroneously described by Sprengel as a *Celastrus*. And 6th. That *Ophira* of Linn. is the same as *Grubbia*, Linn.; but that *Ophira* of Lamarck's 'Illustrations des Genres' is a very distinct genus, which has been lately described by Dr. Klotzsch of Berlin under the name of *Strobilocarpus*; and that the true structure of these genera appears to ally them on the one hand to Hamamelideæ, and on the other to Santalaceæ, to which last, if Dr. Klotzsch's analysis were quite correct, they would decidedly belong.

On an Anomalous Form of the Plum, observed in the Gardens of New Brunswick. By Professor ROBB.

New Brunswick is not favourably situated for the development of Rosaceous fruits. In the summer of 1839, the author had an opportunity of observing the progress of destruction among the plums. Before or soon after the pieces of the corolla had fallen, the ovarium had become greenish yellow, soft and flabby; as the fruit continued to grow, its colour became darker and of a more muddy yellow, and, at the end of a fortnight or three weeks, the size of the abortive fruit was fully greater than that of a ripe walnut, and resembling, in appearance, apricots. When examined they were hollow, containing air, and consisting of a distended skin, insipid, and tasteless. By and bye a greenish mucor or mould is developed on the surface of the blighted fruits, which becomes black and shrivelled, and, at the expiration of a month from the time of blowing, the whole are rotten and decomposed. The flower appears about the beginning of June, and before August there is hardly a plum to be seen. The changes producing these anomalous forms of the fruit were explained on the admitted principles of morphology. The differences from a normal form of the fruit would be found as follows:—the exocarp is yellow and wrinkled, not smooth and red or black; while the mesocarp is as little developed as if the protophyllum had become a leaf. Its cells are loose and dry, while the vessels, large and very prominent, are discerned passing through it. The two largest sets of vessels run up along the inner surface of the groove or suture, corresponding to the line along which the edges of the protophyllum are united, and those which correspond with the radicle in the protophyllum. They all anastomose and converge towards the apex, where all contribute to form portions of the style and stigma. The endocarp was small; it was attached by vascular fibres, but sometimes adhesions existed between it and the mesocarp, on which it lay. Sometimes it was attached near to where the style was given off, in other instances it was midway between that point and the peduncle. In some cases it was empty; mostly one or two ovules might be seen; and one was generally smaller than the other, indicating its deficient nutriment. Each ovule was made up of three transparent shut sacs, the innermost of which (the tercine) contained a transparent fluid, and nothing more. The author supposed this anomalous form of fruit to be influenced in its production by cold winds and long-continued rains at that season at which the flower is open, and the reproductive organs the most exposed to atmospherical vicissitudes. It was popularly attributed to insects; but, from not having observed any, he did not think this could be the cause.

Mr. Babington stated that he had found the *Cuscuta epilinum*, or Flax Dodder, at Burrishoole, in the County of Mayo, in Ireland; and also in a field near to the Crinnan Canal, in Scotland. He also stated,

that it had been introduced into this country with the seed of the flax from the North of Europe, and that there was no doubt of its being distinct from the *C. europæa* of Linnæus.

Sir T. Phillipps, Bart., communicated to the Section a notice of minutely-filamentous roots of the beech, which had grown through the sides of a brick-tank and absorbed the water therein.

He also drew attention to some curious remarks on natural history contained in a MS. History of Wexford, written in 1684, now in the possession of Sir T. Phillipps.

MEDICAL SCIENCE.

An Account of some new Observations on the Structure of the Gastro-intestinal Mucous Membrane, and more particularly of the Gastric and Intestinal Glands. By ALLEN THOMSON, *M.D., Professor of Anatomy in Aberdeen.*

This paper was illustrated by a large series of preparations of the gastric and intestinal glands of Man, and some of the lower animals, amounting to upwards of sixty specimens, which were exhibited to the Section.

The author began by giving a short sketch of the recent progress of the investigations of anatomists respecting the subject of his paper. He referred more particularly to the observations of Boyd, Boehm, Bischoff, Purkinje, Henle and Wasmann, from which the tubular structure of the whole gastro-intestinal mucous membrane, and the covering of every part of that membrane with a layer of nucleated particles or epithelium, has been ascertained, and stated some additional observations of his own in confirmation and extension of these facts. The author then alluded to the very recent observations of Wasmann and of Baly, tending to prove the occasional closed condition of the minute tubes composing the mucous membrane of the stomach in some parts of that organ ; and to the observations of Henle, on the closed vesicular condition or cellular acini of the extremities of the ducts of the salivary, buccal, and some other mucous glands ; and made some remarks on the theory of secretion founded by Henle on these observations, viz. that the matters secreted from the mucous membranes are formed in close cavities or cells, and are discharged by the rupture or solution of the coats of the cells. The theory now mentioned was applied by Henle to the explanation of the closed condition in which the vesicles of the glands of Peyer are usually found ; and Dr. Thomson (without adopting the theory of secretion offered by Henle in its full extent) conceives that the observa-

tions, which he had made at first without an acquaintance with those of Henle, lead to the same conclusion respecting the mode of secretion, in all the gastro-intestinal glands, whether of a simple or more compound structure.

The author gave an account of the structure and general distribution of the gastro-intestinal mucous glands in the human subject under the following heads.

1st. The *glands of Lieberkuhn*, or minute tubes which constitute the greater part of the mucous membrane.

2nd. The simple follicular glands occupying the greater part of the stomach, or *simple gastric glands*.

3rd. The more *compound gastric glands*, observed frequently round the cardia, and more rarely toward the pylorus in the human stomach.

4th. The compound duodenal glands, or *glands of Brunner*.

5th. The aggregated glands of the small intestine, or *glands of Peyer*.

6th. The solitary glands of the small intestine.

7th. The solitary glands of the large intestine.

The author also described the structure and distribution of these different sets of glands in various animals; viz. the pig, sheep and ox, horse, dog, cat and lion, badger, porpoise.

The author then entered into a detail of some observations which he had recently made on the gastric glands, and on the solitary glands of the large intestine, from which he arrives at the conclusion, that at an early period of life these glands have all the form of closed vesicles. This closed condition of the follicular glands he has observed in the stomach of a child eight months old, and in the large intestine of the child at birth. The author adverted to the occurrence of minute vesicles in the stomach of the adult, an appearance mentioned by Boehm and Henle, but one from which the vesicular condition of the gastric and intestinal glands observed by the author is to be distinguished. At the age of sixteen months, a few of the gastric glands are still to be observed in the completely closed condition. At the age of four years they appeared all to be open.

The author found that in the pig two weeks old, only two of the gastric glands were open; all the rest constituted minute closed vesicles.

The author observed that the closed condition of the solitary glands of the large intestine, which belongs to them all at the period of birth, becomes less general and less distinct as age advances; but at the age of two years and upwards he has found occasionally some of these glands closed.

Dr. Thomson then referred to the various opinions of anatomists respecting the existence or absence of apertures in the vesicles composing the aggregated and solitary glands of the small intestine, and adverted more particularly to the observations of Boehm and Krause on this point; he stated that he had frequently observed distinct central apertures in the vesicles conposing the glands of Peyer in the pig, sheep, horse, and occasionally, but more rarely, in the adult human subject,

but not in the child nor young subject. These apertures, which in their general appearance might be compared to the opening of the pupil in the iris, are visible with the unassisted eye, and more easily with a lens of half an inch focus: the vesicles in which they exist are generally empty, or nearly so, of the gray granular matter with which the closed ones are filled. In the pig some of the patches exhibit no open vesicles; others contain entirely open ones; and a third set of patches, which are those most favourable to the observation, contain open vesicles mixed with the closed ones. The open vesicles are more frequently found towards the lower part of the ilium than in its upper part or in the jejunum. The author regards the zone of apertures which surrounds each vesicle of the aggregated glands as merely the openings of the small mucous tubes, and not as excretory ducts of the vesicles, between which and the apertures of the zone he has not been able to trace any communication.

The author entered into various details regarding the minute structure of these glands, and concluded by directing the attention of the Section to the three distinct points which had been the subject of his inquiry, viz.

1st. The closed vesicular origin in the child, and occasional vesicular condition of the gastric glands at a more advanced period of life.

2nd. The closed vesicular condition of the solitary glands of the large intestine at the period of their origin, and the occasional occurrence of this condition at a more advanced stage.

3rd. The occasional open condition of the vesicles of Peyer's glands.

The author further adverted to the bearing of these observations on the theory of secretion in general, on the probable uses of the glandular secretions of the intestine in the œconomy, and on the changes of these glands in the diseased state.

On the Manner in which the Vital Actions are arrested in Asphyxia. By Dr. John Reid.

The two points in the physiology of asphyxia which have of late years principally attracted attention, are the nature of the impediment to the circulation of the blood through the lungs, and the consequent stagnation of that fluid in the right side of the heart, and the large veins leading to it, and the cause of the arrestment of the sensorial functions.

The following experiments were made on this subject. A tube, with a stopcock on it, was fixed into the trachea, and one of Poiseuille's hæmodynamometers was introduced into the femoral artery, for the purpose of obtaining definite information of the force with which the blood was transmitted along the arterial system. The stopcock of the tracheal tube was then turned, and when the state of asphyxia was induced, and the mercury had begun to fall in the hæmodynamometer, a bladder full of pure nitrogen gas was fixed upon the tube secured in the trachea, and the stopcock turned. After the effect of this gas had

been ascertained, a bladder of similar size, containing atmospheric air, was substituted for the nitrogen, and the results compared. The difference between the effects of the respiration of the nitrogen gas and the atmospheric air was most marked; for while the mercury continued to fall in the instrument during the respiration of the nitrogen gas, it rose very rapidly soon after the atmospheric air had entered the lungs. In this experiment, the mechanical movements of the chest, which failed to renew the free circulation through the lungs when nitrogen was inspired, rapidly effected that object when atmospheric air was permitted to enter the lungs even of the same animal, tried subsequently to the failure of the nitrogen, and consequently at a more advanced period of the process of asphyxia. This experiment was repeated several times, and when care was taken to procure pure nitrogen, invariably with the same result. In performing these experiments, a very unexpected phænomenon presented itself. The mercury actually stood higher in the instrument, and the arteries were more distended and tense for about two minutes after the animal had ceased to struggle, or, in other words, had become insensible, and when the respiratory process was nearly brought to a stand, than when it was breathing freely through the tube introduced into the trachea. It was suspected that this arose from an impediment to the passage of the venous blood through the capillary arteries of the tissues generally, by which the force of the left side of the heart was principally concentrated in the arterial system; and on placing a hæmodynamometer in the vein of the opposite limb, and comparing its indications with the other fixed in the artery, this supposition appeared verified. In these experiments it was repeatedly observed, that however rapidly the respiratory movements were performed, provided they were not more forcibly exerted than in natural respiration in the quiescent state, this had no obvious effect upon the force with which the blood was sent along the arteries. Though there can be no doubt that violent movement, either of the muscles of the trunk or limbs, exerts a very marked influence upon the force with which the blood is sent along the arteries (in one experiment the mercury stood nine inches higher in the tube during a violent struggle and a forcible expiration, than during the opposite circumstances of deep inspiration and intermission of the struggle), yet it is obvious, from these experiments, that the impediment to the passage of the blood through the lungs does not depend upon the arrestment of mechanical movements of the chest, but upon cessation of the chemical changes between the blood and the atmospheric air in the lungs.

The explanations which have been given of the cause of the arrestment of the sensorial functions, are two in number, viz. 1st, the circulation of venous blood in the arteries of the brain; 2nd, that it principally depends upon the blood being sent to the brain in diminished quantity, in consequence of the impediment to its passage through the lungs. It has already been stated, that the arterial pressure is not diminished at the time that the animal becomes insensible, and the same thing was repeatedly ascertained in experiments on the veins. The insensibility cannot, therefore, depend upon any diminution in the vascu-

lar pressure upon the brain. It was also ascertained, that though the pulse begins to diminish much in frequency about the time that the insensibility occurs, yet that this has not taken place to such an extent at the precise time when the insensibility has supervened, as to lead us to believe that it depends upon any diminished transmission of blood through the vessels of the brain. From these facts it is concluded, that the insensibility principally, if not entirely, depends upon the circulation of venous blood in the vessels of the brain. It was remarked, that the blood in the exposed arteries was of a decidedly dark hue before the struggles preceding the insensibility occurred, and thus showed the inconclusiveness of those experiments in which unsuccessful attempts were made to induce coma by injecting venous blood slowly into one of the four arteries leading to the brain. In performing experiments upon this subject, it is necessary to bear in mind the exact period at which the insensibility presents itself. A dog generally becomes insensible in about two minutes, to two minutes and a half, and a rabbit generally in about one minute and a half, after the complete exclusion of air from the lungs; so that any experiment made upon the quantity of blood which flows from the cut arteries at periods posterior to this, cannot with safety be adduced in explanation of effects which have previously happened.

On the Anatomical relation of the Blood-vessels of the Mother to those of the Fœtus in the Human Species. By Dr. John Reid.

In this communication it was proved, by preparations laid on the table, that numerous tufts of the placental vessels pass through the decidua and enter by the open mouths of many of the uterine venous sinuses of the mother. Some of these tufts only dip into the open mouths of the sinuses, while others extend their ramification half an inch, and even in some rarer cases more than an inch from the point at which they enter. That these tufts found bathed in the maternal blood of the uterine venous sinuses are prolongations of the fœtal placental vessels, was proved both by injection and by microscopic examination. Dr. Reid then proceeded to point out that each minute placental artery was bound up with a placental vein, and that they terminated in blunt extremities, where these two sets of vessels communicated. The intervals left between the branches of the tufts of the placenta are not filled up with cellular tissue, but the surface of every branch of a tuft is covered by a prolongation of the inner coat of the vascular system of the mother, or at least by a thin membrane continuous with it. This membrane constitutes a kind of sac, with numerous and intricate folds or fringes projecting into its interior. These folds are formed by the covering which it affords to the numerous branches of the placental vessels. Into this sac the blood of the mother is poured by the curling arteries, and is returned by the prolongations of the uterine veins. Each of the uterine sinuses into which the placental tufts project, may be considered a miniature representation of the structure of the placenta;

for we have there fœtal placental vessels, resembling the branchial vessels of aquatic animals, covered by a prolongation of the inner coat of the vascular system of the mother, and hanging in a cavity filled with maternal blood.

On the Anatomy of the Medulla Oblongata. By Dr. JOHN REID.

The object of this communication was to point out the relative position of the motor and sensitive columns of the spinal chord, as they pass through the medulla oblongata and pons Varolii, and the attachment of the different motor and sensiferous nerves to these columns. Dr. Reid produced preparations of the medulla oblongata to show that the decussation of the pyramidal bodies is formed by the greater, and in some cases nearly the whole, of the fibres constituting each of these eminences passing into the posterior part of the middle column of the opposite side. None of these decussating fibres run into the anterior column of the opposite side, nor is there any decussation in the medulla oblongata besides this. On tracing the column which is connected with the olivary body, and which may be termed the olivary column, we find that as it passes downwards it approaches closely to the anterior median fissure immediately below the decussation of the pyramidal columns, and affords attachment to many of the roots of the motor nerves. On tracing this olivary column upwards it is found to expand over the olivary body, affording origin to the hypoglossal and abducens along its anterior margin, and to the porta dura along its posterior margin. Part of this column passes upwards to the corpora quadrigemina, affording origin to the smaller root of the fifth and to the trochleator. Dr. Reid also pointed out how the spinal accessory, and part of the filaments of the par vagum, may be connected with the motor column.

On the Mechanical Functions of the Ear. By Dr. SYM.

The following is a general summary of the contents of this paper.

1. The external ear *protects* the membrana tympani, and contributes to a knowledge of the *direction* of sounds.

2. The membrana tympani is a *passive* medium of communication of vibrations, and the impulses of the air draw its apex *outwards*.

3. The ossicula of the tympanum form a system of levers, by which the extent of the undulations falling on the membrana tympani is *diminished*, whilst their momentum is preserved.

4. Vibrations communicated from the larynx through the temporal bone to the styloid process of the malleus and long crus of the incus, have their extent *increased*, whilst their momentum remains the same.

5. The base of the slopes is drawn *outwards* by the impulses of the air, and performs the action of a piston.

6. The muscles of the tympanum antagonize the impulses, and restore the membranes and bones to their *quiescent* positions.

7. The membrana rotunda receives the *pressure* of the *atmosphere* through the eustachian tube, so as to enable the slopes to be raised.

8. The water of the labyrinth received the full momentum of the impulses of the air on the membrana tympani without loss from condensation, because the difference of the areas of the membrana tympani and fenestræ ovales, combined with the difference of range of motion of the point of the malleus and base of the slopes, is *equal to the difference of specific gravity between air and water.*

9. The perilymph *oscillates* between the two fenestræ, and its alternate fluxes and refluxes over the membranous labyrinth excite the sensation of hearing.

10. The cochlea *regulates* the extent of the oscillations of the perilymph by the expansion of its spiral laminæ.

11. The aqueducts of Cotugno are *diverticula*, by which the perilymph is removed to the cavity of the cranium during the expansions of the spiral laminæ.

12. The petrous bone *deafens* the internal ear, so as to prevent any vibrations from acting on the perilymph, except those which have been previously adjusted for creating accurate oscillations by being transmitted by the ossicula.

On the Connection between the Nervous System and Muscular Contractility. By Dr. John Reid.

This communication was an extension of that made by Dr. Reid to the Association at Edinburgh. In the former communication facts were adduced to show, that when the contractility of a muscular bundle is exhausted in the cold-blooded animals by the application of galvanism, this property of contractility will again return, though all communication between the central organs of the nervous system and the muscles experimented upon had been cut off, by the complete division of the nerves passing between them. In the present communication it was stated that the same fact had been verified upon the warm-blooded animals. The same experiment has also been four times successfully repeated after section of the nerve upon the posterior extremities of the same frog. Dr. Reid then made some observations for the purpose of showing that the experiments made by Müller, and adduced by him in opposition to the Hallerian doctrine of contractility, are liable to a known source of fallacy. The disappearance of the contractility witnessed by Müller in the muscles supplied by the sciatic nerve in a rabbit five weeks after that nerve was divided, was in all probability dependent upon the imperfect nutrition consequent upon inaction. Dr. Reid stated, that he found the muscles of the limb of a frog retain their contractility and their usual size two months after the section of their nerves, when they were daily exercised by sending slight shocks of galvanism through them.

On Foreign Bodies in the Œsophagus. By Mr. George Glover.

On Fibrine of Human Blood. By Dr. Buchannan.

The author presented to the Section the fibrine of human blood, separated from serum, and perfectly free'd from every particle of the colouring matter; he detailed his mode of preparing this constituent, which was by carefully introducing a given quantity of recently drawn blood into separated serum placed on a filter: the red particles rapidly fall to the bottom of the fluid, and the fibrine of the introduced blood is free'd from its portion of serum by the filtration of this fluid through the coloured particles, or through sand spread on the bottom of the filter.

On some of the Functions of the Fifth Pair of Nerves, and of the Ganglia, &c. By N. Fowler, *M.D., F.R.S.*

The following subjects were discussed.

1. A sensation (probably in the adductor muscles of the eyeball) induced by approaching a metallic point to the forehead, between the eyes.
2. Whether muscular adjustments do not in all the senses precede distinct sensation?
3. Whether thought and adjustment are not reciprocal?
4. A demonstration of a re-transmission through the lenticular ganglion to the iris.
5. Moisture necessary to sensation.
6. Instances of re-transmission from one organ of sense to another.
7. Facts in proof that a branch of the fifth is the nerve of taste.
8. Facts in proof that sensibility and contractility are not supplied by the brain, but by the local arteries.

On the Preservation of Subjects for Anatomical purposes. By Dr. Rees.

On the Uses of the Conglobate Glands. By Dr. Jeffreys.

The object of this paper was to show that these glands aided in propelling, like little hearts, the fluid through the lymphatics.

On the Therapeutic Effect of Croton Oil in certain Nervous Disorders. By Dr. Patrick Newbiggin, *of Edinburgh.*

In this paper Dr. Newbiggin demonstrated that, independent of its well-known purgative properties, Croton oil possessed specific influence in epilepsy, and in the various forms of neuralgia, as in tic-doloureux, sciatica, &c. Dr. Newbiggin was induced to form this opinion in

consequence of his experience of the treatment of such complaints at the New Town Dispensary of Edinburgh, as well as in private practice, where he had administered the oil of the *Croton Tiglium* in a large number of cases. The author selected some of the cases, particularly of epilepsy, wherein he had produced entire relief from that very grievous malady, and he mentioned especially one instance where a cure had been effected after this disease had existed for upwards of twelve years.

On the Effects of Air when Injected into the Veins. By Dr. J. R. Cormack.

The author objected to the theory published by Sir Charles Bell, who ascribes death, when it takes place, to the effect which the air produces on the medulla oblongata. This Dr. Cormack denied, and stated that it requires a large quantity of air to be injected in order to produce death, when, in every instance, the heart was found distended in its right cavities, and its functions arrested from this cause. Dr. Cormack communicated some notices of the diseases occurring in Tangier in Barbary, the principal of which are elephantiasis, inguinal hernia and hydrocele, with every form of dropsy. Intermittents are frequent, typhus rare. When cholera broke out, upwards of one-tenth of the native inhabitants perished in a few months; the Moors, being fatalists, took no precautionary measures, whilst of the 300 Christian inhabitants not more than two or three perished.

On Mnemonics. By Dr. MacDonald.

The object of the paper was to show grounds for a new and more philosophical classification and treatment of insanity. It is incapable of abridgement.

On the Physiological and Medicinal Action of Bromine and its Compounds. By Dr. R. M. Glover, *Lecturer in the Medical School of Newcastle. Communicated by Dr.* J. Reid.

The study of the physiological action of remedies bears the same relation to therapeutics as physiology itself to pathological science; and thus, as the investigation of this subject seems well calculated to throw light on the physiological actions of chlorine and iodine, which cannot, like bromine, be exhibited pure in experiments, it seems worthy of being pushed as far as possible.

Whether bromine be taken into the lungs in the form of vapour, or in the fluid form into the stomach, or injected directly into the circulation, it acts purely as a corrosive and irritant. Its action on the primæ viæ is different from that of hydrobromic acid, into which bromine is converted when absorbed into the circulation. The author extends this observation by analogy to chlorine and iodine, and their respective hydracids.

Bromine exerts an action on the rectum like that of iodine; it is also tonic and diuretic. Its remedial virtues are chiefly conspicuous as an external application in the treatment of scrofulous, syphilitic, malignant and specific ulcers. In these cases it appears to act as an excitant, and by diminishing the fœtor, and perhaps as a mild caustic. It appears also, from some cases observed by the author, to be a useful remedy in some chronic diseases of the skin.

The bromides of potassium, sodium, barium and mercury, resemble much more the chlorides of those bases than the iodides in their physiological action. The bromide of potassium is a good tonic. The bibromide of mercury has no advantage as a remedy over the bichloride, contrary to what has been asserted in France.

The bromide of cyanogen has a double action; in a powerful dose it acts like prussic acid; in a more moderate dose it occasions most violent symptoms of irritant poisoning, and is perhaps the most powerful irritant known. Ammonia is its best antidote.

The chlorides and bromides of olefiant gas, likewise chloroform and bromoform, exert a very remarkable physiological action, whether introduced into the stomach or injected into the circulation. In the former case they produce in a large dose death by coma; in a smaller dose loss of power over the voluntary muscles, sensibility being retained, along with symptoms of obstructed respiration, arising from effusion into the lungs. In such cases the mucous membrane of the stomach is found blackened, and the lungs congested; the bronchi filled with frothy serum, and here and there spots of pulmonary apoplexy in the substance of the lung. When injected in large quantity into the blood, these substances cause almost instant death, producing great congestion in the lungs, and destroying the irritability of the heart. In smaller doses they produce death in the course of a few hours, with much the same symptoms as those which attend their introduction into the stomach.

On the Treatment of Pertussis by Cold washing of the Chest. By Dr. Hannah.

The chest is to be freely yet rapidly washed with the coldest water, to which a little vinegar, alcohol or Eau de Cologne is added, and immediately rubbed most firmly with a hot towel, to produce very decided reaction on the surface; to secure this the washing is to be done in an apartment of at least comfortable temperature, or the patient put into bed. By this, repeated three or four times daily (at least morning and evening), the disease, he averred, is cut short, in many instances mitigated, and its course abbreviated in others. Several cases illustrative of this were read. He advises it in all stages, and would not be deterred from using it in bronchitis; and though not certain of the propriety of it in peripneumonous complication, he is not inclined to regard that as a decided contra-indication of the remedy in question. He referred its usefulness in this disease to its rendering the system unsusceptible to cold (one great, nay, the greatest cause

of danger during the persistence of pertussis), to its power of allaying febrile heat, its well-known efficacy in chronic bronchitis, its rubefacient power when done in the manner he directs, its tonic and invigorating action, particularly on the digestive organs, and regarded its efficacy in allaying spasmodic action, as essential in explaining its virtues in this disease.

On the Circumstances which govern Local Inflammation, the effusion of Coagulable Lymph, and the formation of Pus, as the Sequelæ of Disease, Accidents, Surgical Operations, &c. By Dr. PERRY.

After pointing out the phænomena of inflammatory action, its dependence upon nervous energy, and the various opinions entertained by pathologists respecting this and the formation of pus, none of which appear to the author to account in a satisfactory manner for the phænomena, all being either unsupported by facts or positively contradicted, reference was made by him to the tables of the appearances presented on post-mortem inspections. It was found, that out of 1078 cases of fever, all males, 155 died, and before being dismissed, 93 were seized with local affections, of which 44 died. On inspection it was found, that in the head the membranes were more vascular than usual in 85; that an effusion of serum in the subarachnoid membrane, amounting to from $\frac{1}{2}$ oz. to 5 oz., existed in 99; and at the base of the brain, and in spinal canal, in 83; and of purulent effusion into ventricle or surface, 3; there was recent effusion of coagulable lymph in the right side of chest in 24; in left side, 8; in both sides, 13; recent pneumonia and hepatization of right lung, 14; of left, 8; of both lungs, 3; of gangrene of lungs, 3; old adhesions of right side, 30; of left, 24; of both, 21; heart softened in 72; blood dark and fluid in 87; vascularity of stomach in 69; of small intestines, 60; of colon, 33; enlargement of aggregate glands of intestines, 66; of solitary glands, 19; of mesenteric glands, 25; spleen softened, 99; enlarged, 30; and so of other organs.

From the universally admitted facts, that whenever the patient was much reduced in strength, or of a weak and strumous habit, or had been weakened by long confinement or severe suffering, irritative fever, with suppuration, was often the result: thus in local inflammation, the effusion of coagulable lymph, or the deposition of pus, occurred most frequently after adynamic fevers, when the brain and nervous system had suffered severely; so often other contagious exanthematous fevers (none of which the author considered in the first instance as inflammatory) were viewed as the result of a change produced upon the blood and the capillary vessels by the previous shock, or over excitement. In fact, Dr. Perry thought that the congestion of the vessels, the effusion of coagulable lymph, serum and pus, were the result of innervation; and the rapidity with which such products were formed might be taken as a test of the extent to which innervation of the blood and of the vessels, local or general, existed. To remove this state by restoring the equilibrium of action, was the object of the physician.

On the Chemical and Medicinal Properties of the Matias Bark, which is employed in Columbia, South America, as a substitute for Cinchona. By Dr. MACKAY.

The nature of the tree which produces this bark has not been ascertained, but from an examination of the properties of the bark, it is in all probability correctly supposed to be of the family Winteraceæ. The bark is sent to this country in pieces, which differ much in size and form. Its colour is either a pale fawn or brown internally, and brown externally. It has an agreeable and aromatic smell, and a bitter and rather pungent taste.

When distilled with water it yields a considerable quantity of essential oil, which separates into two distinct portions, one floating upon the surface of the water which distils along with it, while the other sinks to the bottom of the receiver. These oils differ in colour, in smell, and in specific gravity.

Eight pounds of bark yield one pound of watery extract, which has an intensely bitter but agreeable taste, and a deep black colour. By acting upon this extract with æther, adding a large quantity of distilled water, then filtering and evaporating to dryness repeatedly, the bitter principle was, it is conceived, obtained free from impurity, with the exception of colouring matter, which it has been found impossible to separate, on account of both being simultaneously taken up by animal charcoal.

The bitter principle, as thus obtained, is a brown extractive substance, soluble in æther, alcohol and water, which possesses neither acid nor alkaline properties, but has an intensely bitter taste.

From the investigation which has been made into the properties of this bark, in several public institutions, they are ascertained to be tonic, febrifuge and carminative, or stimulant. It has been successfully administered in intermittent fever, in convalescence from continued fever, in hemicrania, in dyspepsia, and in a variety of chronic affections in which tonics and stimulants were indicated. As an adjunct to diuretic medicines it has been found eminently useful.

The author exhibited specimens of the bark, of the oils, bitter principle, watery extract, and essence obtained from it, and concluded by expressing his deep obligation to R. Mackay, Esq., British Consul at Maracaibo, and to Signor Gonsales, for having devoted much time and attention in procuring for him the valuable substance, which he had now the honour to introduce to the notice of the profession.

On the Laws which govern Contagious Fevers, the circumstances which favour their diffusion, and the mode by which they are communicated from one individual to another. By Dr. PERRY.

After some remarks showing that there was nothing peculiar to Glasgow in the site or want of cleanliness that was not to be met with in other large cities, he concluded that the chief cause of the diffusion of contagious fevers arose from the poor crowding into Glasgow from

country districts where these contagious diseases did not prevail, when they became the victims of contagious fevers by mixing with that class among whom they were seldom absent. He then considered those laws by which contagious fevers were governed: such as, that when once the disease had commenced it could not be checked, but must run its course; that at a certain period of the disease it was characterized by an eruption upon the skin; that this eruption was diagnostic, and that, as a general rule, an individual having once undergone the disease was secured against a second attack; that these laws were as certainly applicable to typhus fever, as to any of the other exanthematous fevers. These points were illustrated by carefully drawn up statistical tables of the patients admitted into the Fever Hospital under the care of the author. These tables show that about 90 per cent. of those admitted had the diagnostic eruptions; of the 10 per cent. who had not, $5\frac{1}{2}$ per cent. were affected with diseases chiefly local, which were not typhus; $2\frac{1}{2}$ per cent. were admitted at a period when the eruption had disappeared; and in the remaining 2 per cent. the eruption was so scanty and evanescent, or the skin so brown and dirty, that it could not be detected, though the patient had the other symptoms of the disease; rather less than 2 per cent. were stated to have a second attack. Other tables were given of the different ages and the comparative mortality at each period, the country to which they belonged, showing that the Scotch formed about 66 per cent., the Irish about 35 per cent., and English and foreign about $2\frac{1}{2}$ per cent. With respect to the mode by which it was communicated from one individual to another, he believed it was not communicable before the tenth day, and gave a number of cases to show that it was always during the convalescent stage that the infection was spread, which he supposed was the case with all the exanthematous fevers, by the desquamation of the cuticle, as in measles, scarlatina and small-pox; and this he thought accounted for the difficulty of tracing the contagion, persons being capable of communicating the disease as long as the desquamation was going on. He had made some attempts to inoculate the disease in young persons by scraping off the cuticular eruption with a lancet, but had failed, which he considered would be a desideratum, as he found the disease in the young mild in character, and attended with little danger, and was quite satisfied, that could means of communicating the disease be accomplished, it would be found as effectual in securing the patient against a second attack of typhus, as inoculation does against small-pox. The means of preventing the disease from spreading, is by isolating the patient during the convalescent state, thoroughly washing the body, cleansing the clothes and exposing them to a high steam heat; and Dr. Perry recommended the establishment of Boards of Health in the different cities and counties by the Government.

Notice of the Disease known by the name of Mal d'Aleppe. By Dr. CHARLES W. BELL, *Physician to H. B. M. Legation in Persia.*

Dr. Bell having had opportunities of observing this curious disease during his residence in Persia and Arabia, thought that a notice of

some of its peculiarities might be interesting; for though frequently mentioned by travellers in Syria, Arabia and Persia, under the names of Aleppo button, Bagdad boil and Date mark, and also lately met with in the north-west provinces of India, no full description of the disease is to be met with in any of our systematic works. In Arabic it is called Khorma, or the date disease; in Persian Salek, or the disease of a year; and is so prevalent in these countries, but especially in the towns of Arabia, that scarcely any one, whether native or European, escapes its attack.

The disease commences like small pimples, which very gradually increase in size till they appear as ulcers covered with a dry crust, resembling that of Rupia syphilitica, with a small quantity of pus under the scab. These occur on different parts of the body at the same time, chiefly on the hands and legs of adults and the faces of children, but generally attended with little pain. They have always so much of the character of syphilitic sores, as to mislead any one previously unacquainted with the disease, and as they continue to increase in size for a year, they occasionally present a horrible carcinomatous appearance. At the expiration of twelve months from its commencement the different ulcers suddenly heal of their own accord, leaving an ugly indelible scar.

The natives make an absurd distinction of the disease into male and female, the sores of the former kind being larger and enduring for a year; those of the latter smaller and healing in six months. Dr. Bell considered the disease worthy of attention, not only on account of its great prevalence and the disfigurement produced by it in these countries, but as an instance of a disease attacking the constitution without fever or other symptoms, wearing itself out in a certain time, unaffected by treatment, by local applications, never appearing a second time in the same person, and occasionally driven out of the system by the attack of a more powerful disease, such as plague or typhus.

In the treatment of the disease he has found the internal use of iodine and sulphureous baths beneficial, but has never succeeded by the use of any external application to a single sore in causing it to heal a day sooner than the other coexistent ulcers purposely left untreated.

Dr. Bell conceives that the extreme dryness of the atmosphere in all the countries where this disease is prevalent may exert a predisposing influence, but considers it strictly a contagious disease, propagated chiefly by the use of the public baths. It is difficult to say how long it may lurk in the system without making its appearance, but instances are numerous in which it has not shown itself till several months after the return of persons to this country from their travels in Syria and Arabia.

By the natives it is not attributed to contagion, but to fanciful causes, such as eating dates, and is believed by them incurable till its destined period be expired, and they consequently very seldom submit to medical treatment, using only a few ineffectual local applications, a prejudice which unfortunately very much limits the means of ascertaining by experience the most efficacious mode of treatment.

On the Operation for Squinting. By Mr. A. URE, *of London.*

As a diversity of opinion prevails among surgeons as to the ultimate success of Professor Dieffenbach's operation for the cure of strabismus, Mr. Ure was induced to lay before the Meeting the result of seventy-two cases (thirty-two males and forty females), in which the section of one or other of the muscles of the eye had been performed by himself. These were drawn up in a tabular form, including age, duration of the infirmity, cause, eye affected (right twenty-nine, left thirty-seven, both six), state of vision before operation, state of vision after, colours of iris (hazel twenty-eight, gray thirty-one, grayish blue two, blue ten), and result (cures sixty-six, of which nineteen are 'perfect,' and twenty-one have fullness or other slight affection). In six cases the result was 'amendment.' The author described his process and after-treatment.

A Description of a double Monocephalic Human Monster, which was transmitted to this country from South America, by K. MACKAY, *Esq., British Consul at Maracaibo, Venezuela.*

The subject of this paper was born at Maracaibo, Venezuela, South America, in the month of March 1840. It is the offspring of a negress, and is reported to have been born alive, but to have died a short time after its birth. It is of the female sex, and seems to be composed of two equally developed bodies united together from the umbilicus upwards, bearing four arms and four legs, and having only one neck and head common to both.

A minute account of the dissection was given, of which the following is a summary.

The spinal and ganglionic nervous system were double, while the central was single, each corresponding with the organs which they were destined to supply.

The organs of mastication and of deglutition were single, as were also those of digestion, with the exception of the inferior portion of the alimentary canal, which at a certain point became double. The respiratory organs were the least developed and the most anomalous in their character, there being two lungs situated in their usual position, and a third lung lying upon the posterior sternum, which seemed to belong equally to both bodies. With the exception of the heart and the vessels which supplied the head, neck, and such organs as were single, there were two complete arterial and venous systems, which, with insignificant varieties, were disposed in the usual manner.

The urinary and genital organs were double, and well developed.

On the Results of Amputations. By Dr. LAWRIE.

In this paper Dr. Lawrie gave tables stating the results of 276 amputations which took place in the infirmary of Glasgow, during several years. The cases were classed according to the sex, the limb operated

on, and the causes rendering the amputation necessary, whether from disease previously existing or from accident. Some of these results were as follows: of the 276 cases, 216 were males, of whom 86 died; 60 were females, of whom 14 died; 153 were from previous disease, of whom 35 died. In operations at the shoulder the deaths were equal to the recoveries; of the arm, the deaths to recoveries were as 3 : 14; of the leg, as 1 : 2; at the wrist, at one period, as 1 : 29; in another period as 8 : 22.

On Opacity of the Cornea produced by Sulphuric Acid. By R. D. Thomson, *M.D.*

The rapid destruction of vision, when sulphuric acid is brought into contact with the cornea, has long been known to surgeons. The subject came under the author's consideration from having attended a case along with Dr. Maddock, in which the vision of the right eye was destroyed, in consequence of a woman having thrown a quantity of oil of vitriol at a man in a fit of passion. The corrosive fluid, according to the statement of the sufferer, was only in contact with his eye about two minutes, when he had an opportunity of washing it off with water; yet permanent opacity of the cornea had taken place. It naturally occurred, from a consideration of this statement, that the agency of the acid could not have extended to any very considerable depth. The anatomical structure of the cornea likewise favoured this conclusion. The author described the laminar structure of the cornea, and the additional investment of the conjunctiva, and drew attention to the effects of heat, nitrate of silver, &c. on these structures. When sulphuric acid or common oil of vitriol is brought into contact with the dead cornea of the sheep, in three or four seconds, if the experiment be watched under the microscope, the acid, which appears to swim about freely on the surface of the cornea, produces a milkiness; in half a minute a white opacity; and in from one and a half to two minutes all translucency is destroyed. If the cornea, which has been previously extended on glass, be now plunged into water and washed free from sulphuric acid, a permanent opacity will be found to have taken place, precisely as in the case of those unfortunate individuals who have been deprived of vision by sulphuric acid in the manner already described. If we now make a section of the cornea which has been acted on by the acid, we shall find that the action has been very superficial, and that the upper and under surface of the opake portion are parallel, and hence the influence of the acid would appear to have extended equally. If the section be now made at right angles to the axis of the eye, so as to separate the opake from the uninjured portion, the transparency of the cornea appears to be perfectly restored, and the only defect, when a careful examination is made by the microscope, appears to proceed from the uneven surface produced by the section. But the opake portion may likewise be readily separated by scraping it with the point of a knife, so decided is the limit between the uninjured and opake surfaces. It would appear from these facts, that the action of

the sulphuric acid is to produce a new or false membrane, which is no removed by nature, as some other false membranes are, in consequence of its forming part of a solid body; they serve also to confirm the opinion stated by the author in a communication read at the Bristol meeting—that false membranes, as in croup, balanites, bronchitis, &c., are the consequences of the presence of an acid preternaturally secreted in the fluids of the mucous membranes where these deposits occur, the organization of the albumen taking place under the coagulating influence of the acid. The treatment of opacity of the cornea produced by the action of sulphuric acid, appears to be elucidated in no small degree by these facts; if the acid be neutralized in the course of a few seconds, little or no injury is sustained by the cornea; but as in thirty seconds considerable opacity has occurred, and some portion of false membrane has been formed, it will be necessary to have recourse to the knife, which may be safely employed to scrape off the preternatural deposit. The author observed, that he intended to propose the operation to the patient described, so soon as the granulating action now affecting the eyelids had been subdued.

Notice of an Ossified Tendo Achillis, and of a Case of Exostosis. By Dr. H. LONSDALE, *of Edinburgh.*

The author considered the former preparation unique, not being aware of any similar preparation in the museums of this country.

The latter preparation illustrated osseous deposits in the tendon and muscular fibres of the crureus muscle, and an extension of this ossification to the femur itself, resembling an exostosis, but differing from the common exostosis in growing *to*, and not *from* the bone. The author designated it by the term *Exostosis from without.*

The object which the author had (as stated in a brief communication) in exhibiting this latter preparation to the Section, was to counteract those exclusive opinions which many entertain on the subject of ossification; and he considered that it was of value in showing that bone may be formed by vessels belonging to the soft parts, even in muscular fibres adjacent to one of the long bones, and more especially in pointing out the caution which physiologists ought to observe in placing a limit to nature's power.

On Dislocation of the Ankle-joint forward and backward; and on the Reproduction of Bone after the Operation of Trepan. By JAMES DOUGLAS, *Lecturer on Anatomy, Glasgow.*

There is no satisfactory example on record of dislocation of the ankle-joint without fracture of one or both malleoli. There is no case on record of *complete* dislocation of the tibia forward, so that the inferior articular surface of that bone shall be completely in front of the articular surface of the astragalus. A case has occurred to the author of this

very rare accident, exactly similar to that described by Mr. Adams in the Cyclopædia of Anatomy, article Ankle.

A woman aged sixty died in the Glasgow Royal Infirmary in 1834, having an unreduced dislocation of left ankle forwards, of two years standing. The toes were pointed down, the ankle being stiff, in a state of complete extension. A deep curve is seen behind, where the tendo achillis should be straight; the heel is lengthened, and the fore part of the foot is shortened. The anterior edge of lower end of tibia makes a projection in front, and a notch exists below it, between it and dorsum of foot. Outer ankle is in its proper place, but inner one is thrown forward about $\frac{3}{4}$ths of an inch. On dissection, tibia is found above $\frac{3}{4}$ths of an inch further forward than natural; its anterior edge being exactly over articulation of astragalus with os naviculare, and nearly $\frac{3}{4}$ths of an inch above it, so that a small part of scaphoid cavity of tibia behind still rests on the pulley of the astragalus. The tendon of the tibialis anticus by this means runs in a straight line to its insertion at the internal cuneiform bone, instead of curving forward. Behind, the astragalus projects so much, that the flexor longus pollicis does not run in its groove on the tibia at all. Astragalus and os calcis are in their proper relation to each other. External malleolus remains in its place, with the ligaments entire. A hollow mark runs upward and backward from its anterior edge, showing where fracture had occurred; the superior portion being thrown forward along with the tibia. Some new bone is deposited on their junction. The peronæal tendons preserve their proper relations. Internally, the deltoid ligament has been ruptured.

Neither Sir A. Cooper nor Dupuytren has ever seen a dislocation backward. Those cases which have been supposed to be such, have probably been fractures close to the joint, like the following.

A man aged forty-one was admitted into the Glasgow Infirmary in 1834, having injured his left ankle three years previously by a fall, being struck on front of leg, immediately above joint, by a plank. Some portion of tibia was felt attached to astragalus, while shape of tibia was thrown backward. Considerable doubt existed whether fibula was fractured or dislocated. Leg was $\frac{3}{4}$ths of an inch shorter than right, and foot was very long in front, and very short behind. When he walked, lower end of shape of tibia pressed against tendo achillis, making it project backward, and causing acute pain. The foot was amputated.

On dissection, tibia and fibula are found fractured transversely, immediately above ankle-joint. Each malleolus remains in its proper situation. A thin arch of the tibia, not a quarter of an inch in thickness, remains over astragalus, and has formed a ligamentous connexion with its articular surface. Fractured surface has become smooth, and covered with a periosteum. The shafts of the bones pass backward and downward; their extremities are covered with cartilage, and have received new fibrous capsules, derived from the deep fascia of the leg, in front and on each side of the tendo achillis. End of tibia does not rest on os calcis, but presses downward and backward against the tendon.

Mr. Douglas has since seen another case precisely similar to the above.

It is stated by Professor Cooper, in his Surgical Dictionary, that reproduction of bone in the cranium is rare, and that the deficiency of bone is never entirely obviated. A portion of the frontal bone which the Author laid before the Section exhibits a trepan-hole completely filled up with bone.

The man from whom it was taken died at forty years of age. "I observed a conical scar on his forehead, and felt a depression, and inquired its history. When a lad of twelve or fourteen he had got his head fractured in a fight, and was trepanned twenty-six or twenty-eight years before his death. I found the edge of the trepan-hole well marked by a regular depression of about $\frac{2}{3}$rds of an inch, while below the depression was irregular, probably from some splintering having taken place in that direction. The bone which fills up the hole is compact and translucent, except at lower part, where it is thickened, and projects a little internally. The mark is just above the upper termination of left frontal sinus, and in situation of frontal eminence, which is destroyed by it. This preparation, of course, settles the question of the complete filling-up with bone in the affirmative."

On the Vital Statistics of Scarborough. By JOHN DUNN, *Surgeon.*

As Scarborough is the principal watering-place in the North of England, it is of great importance to know accurately the prevailing causes of death, their relative proportion, the least and most healthy periods of the year, the ratio of mortality according to age, the climate as to temperature, variation, atmospherical pressure, fall of rain and prevailing winds. These are illustrated by tables, proving among other points that the deaths from typhus and scarlatina are very low, the former being as 4 to 11·64 of the same mean population of the kingdom. As to pulmonic diseases, so generally dreaded on the sea-coast, the author observes, "It is a gratifying, and in some measure an unexpected fact, that diseases of the respiratory organs, so fatal in general, do not bear so large a proportion in Scarborough to the general mortality as in the mean population of the whole kingdom. With us they amount to 1 in 5·09 of the whole deaths, in the kingdom they form the prodigious number of 1 in 3·67. The relation to the number of inhabitants is also in our favour, being 1 in 197·91, while in the mean population of the kingdom it is 1 in 181·65. With respect to consumption a remarkable fact must be noticed, that only 5 cases are registered in the month of March for the three years, and 4 for April; it must be further observed, that in the first year there is but one death in March from this cause, and none in April, either of the first or second years. Instead of the spring months being so fatal to phthisical people, it appears that the greatest number of deaths took place in July, the hottest month of the year."

"As to the chance of attaining longevity at Scarborough," Mr. Dunn states, that, "In every 1000 deaths in the whole kingdom there are 145 at the age of 70 and upward; in the same number in London 105,

Birmingham 81, Leeds 79, Liverpool and Manchester 63. In Scarborough it ascends to the high number of 195, giving to its residents more than double the chance of attaining old age over many of our populous towns, and three times the chance over Manchester.

"Turning our attention from the oldest periods of life to the youngest, we shall find that the deaths under one year for 1000 of all ages are 214 for the whole kingdom, 277 for Leeds, 237 for the East Riding, 191 for the North Riding; and notwithstanding the fatality of the measles in the first of the 3 years, only 181 for Scarborough."

In the notes on the climate he says, "The remarkable mildness of the winter and summer months here is deserving of attention. It might scarcely be imagined, that in the severe winter of 1838 we had only 40 days or nights in which the thermometer was ever seen at or below the freezing point, while in London there were 44 and in York 70. There were also only two days in which it did not rise above 32° during some part of the day, in London there were 18. The thermometer on the 19th of January 1838, was 30° at Scarborough, 2° at York, and 13° in London. For the last eight years the thermometer has never fallen lower than 20°, nor risen higher than 83°.

"In the hottest year, 1834, the thermometer will be found in the Tables to have been 39 days from 70° and upward, and 76 days above 65°. This was one of the most sickly seasons I ever knew. One of the healthiest was perhaps the last, which was the coldest, only giving 4 days for 70° and upward, and 27 above 65°. So remarkably mild are the winters in general at Scarborough, that there have been only 5 days in the eight years (including that of the severe frost) in which the thermometer was as low as the freezing point during the whole day, and 202, or 25·16 in a year, in which it descended to it during the lowest range in the night or day." The mean temperature for the year is 47°, and mean daily range 8° to 9°. The prevailing winds are westerly, being

Westerly, 612.	North, 137.
Easterly, 367.	South, 121.

"The mean annual fall of rain is 22·10 inches."

Tables were given, illustrating the number of deaths under different conditions of the atmosphere.

Sir David Dickson communicated descriptions of several cases, which were read to the meeting by the Secretary.

STATISTICS.

On the State of Crime within Glasgow and City Police Jurisdiction. By Captain Millar.

The following are extracts:—

"Population of Glasgow, within the Police Jurisdiction, supposed to be	175,000
Population beyond Police Jurisdiction, and within the Parliamentary boundary, supposed	97,000
	272,000

"*Extent of Crime.*—During the year ending the 31st of December 1839, the number of persons brought before the Magistrates of the city, including parties charged with contravening minor police regulations, as well as parties charged with crimes and offences, was 7687, the males being in the proportion of three to one of the females. Of the total number, 468 were discharged, 5410 summarily convicted, 661 sentenced to Bridewell, 46 sentenced to jail, 179 acquitted, 1178 admonished, 72 ordered to find bail, 306 transferred to the Burgh Criminal Court, 72 to the Sheriff Court, 55 to the Justice of Peace Court, and 20 were sent to other counties. The estimated value of the property stolen within the police bounds, and reported at the office during the year 1839, including watches and money taken from the persons of individuals in a state of intoxication, was 7653*l.* 10*s.*; the estimated value of property recovered 1260*l.* 10*s.*; the number of attempts at housebreaking, discovered by the police, 84; the number of criminal informations lodged in the course of the year, 3725; and the number of cases actually brought into court, 5047. The aggregate number of offenders includes many parties who re-appeared. The preceding statement and relative table apply solely to the city of Glasgow Police jurisdiction, exclusive of the suburban districts; but it is right to state, that a very large number of the offenders within the city truly belonged to the suburbs. Nearly all the thefts of watches and money taken from the person, and those by domestic and other servants, were committed in circumstances beyond the control of the police, and where they could not act in a preventive capacity.

"Notwithstanding the increase in the population of the city and suburbs, the amount of crime has of late years diminished. This is satisfactorily shown by the diminution of the number of police cases of every description, with the amount of fines levied for petty assaults, disorderly conduct, &c. The number of persons sent to the Glasgow Bridewell from the Justice of Peace Court for offences of every kind, in the year 1836, was 224; in 1837, 412; in 1838, 401; in 1839, 498; and for the period ending 18th of August 1840, 535. Of those offenders, during the two years ending 18th of August 1840, 137 were sent to Bridewell for periods of from 5 to 60 days, for the non-payment of fines, varying from 5*s.* to 5*l.* The number of persons

sentenced to be executed in Glasgow, from the years 1820 to 1840, both inclusive, was 66, of whom 45 were hanged, and 21 had their sentences commuted to transportation for life. Of the persons executed, three were females. There have been only four executions in Glasgow since 1833; three for murder, and one for throwing vitriol with intent to murder.

"The number of houses of bad fame within the royalty is 204. The total number of females ascertained by the police to frequent houses of bad fame within the royalty, is 1475.

"*Fires.*—The number of fires in the city and suburbs, from 1st of January 1836 to 31st of January 1839, being three years, was 268. Of these, in nineteen instances, the premises were totally destroyed; in sixty-four considerably damaged; and in 185 slightly damaged. In 232 instances the causes were ascertained, and were very varied; in thirty-one the causes were not ascertained; and in five the fires were considered wilful, the parties having been taken into custody, and the cases reported to Crown counsel. The most frequent cause was found to be from flues and stoves taking fire through carelessness.

"*Publicans.*—In the year 1839, there were within the royalty of Glasgow 1220, and within the suburbs 1080 licensed public-houses and other places for the sale of excisable liquors—in all 2300.

"*Pawnbrokers.*—There are 33 licensed pawnbrokers, and about 400 small unlicensed brokers within the royalty.

"*Health*—In the very centre of the city there is an accumulated mass of squalid wretchedness, which is probably unequalled in any other town in the British dominions. In the interior part of the square, bounded on the east by Saltmarket, on the west by Stockwell-street, on the north by Trongate, and on the south by the river, and also in certain parts of the east side of High-street, including the Venals, Havannah, and Burnside, there is concentrated everything that is wretched, dissolute, loathsome, and pestilential. These places are filled by a population of many thousands of miserable creatures. The houses are unfit even for styes, and every apartment is filled with a promiscuous crowd of men, women and children, all in the most revolting state of filth and squalor. In many of the houses there is scarcely any ventilation, and, from the extremely defective sewerage, filth of every kind constantly accumulates."

On the Normal School of Glasgow. By Mr. Leadbetter.

The Glasgow Educational Society's Normal School was established in 1826–27, first, for the training of infants, and since 1831 for the children of all ages from two to fourteen. At present the number attending is 500; the children receive Bible and secular training, and at play they are superintended by the masters; the lessons are received by them in a gallery simultaneously. There is also a school of industry for females, and lately a private model class for the wealthier classes has been established.

The branches taught are English, reading, grammar, geography, history, elementary outlines of science, Bible training, writing, arithmetic, mental and by pen, mental and written correspondence, architectural drawing, to which are added in the private classes, Latin and practical mathematics. Fee for the infants, 2*s.* per quarter, and for juvenile classes, 3*s.* per quarter. The private model class for the middle society, 1*l.* 1*s.*; initiating, and others more advanced, 2*l.* 2*s.* per quarter.

The period of attendance by the teachers who receive instruction in the art of teaching is six months, but it is intended to extend it to twelve months; the average number attending is between forty and forty-five, and 602 male and female teachers have been instructed, and received appointments in Great Britain, Ireland and the Colonies. Fee, 3*l.* 3*s.* each student.

The various classes are under the charge of masters, and a rector and four masters are specially appointed for the instruction and the training of the Normal students. The students are required, previous to admission, to produce certificates of moral character.

The Normal Seminary is under the same superintendence in religious matters as the parochial schools of Scotland, and the children of parents of all religious denominations are freely admitted, and no questions asked.

The Normal Seminary has cost 15,000*l.*, of which Her Majesty's Government granted 4500*l.*; 3500*l.* has been obtained by private subscription, and the remaining 7000*l.* stands as a debt on the property.

On the Glasgow Asylum for the Blind. By Mr. ALSTON.

By the system of printing in relief in Roman letters, adopted in this institution, an easy method is opened of communicating information to the blind. After the pupils have acquired a knowledge of the shape of the letters of the alphabet, words of two or three letters are submitted to their touch. They are then made to feel the words with two or three of their fingers on adjoining letters, by which means they are able to decipher two or three letters at once, which, by practice, will give a dexterity and fluency to their reading. They are then taught orthography, and next proceed to study the derivation of words and their relation to each other. By this system of tuition, the sense of touch becomes the channel through which instruction is conveyed to the understanding and the memory. The branches of education taught in this Institution are reading, English grammar, arithmetic, geography, and the elements of astronomy and geometry, music, &c. At present there are above twenty individuals, whose ages vary from ten to twenty-two years, who can read; and the attainments of some of them will bear a comparison with those of the same age and time under tuition who are in possession of every natural advantage. One of these is a young woman, who, after being educated in the Institution for the

Deaf and Dumb here, lost her sight about seven years ago. She may now be seen daily receiving instruction from one of the more advanced blind children, tracing by the touch the form of the letters, which she still remembers, and then indicating them by spelling the words on the fingers to her blind companion. Afterwards she takes her slate and writes down the passage she has read. The restoration of this interesting individual to intercourse with the rational world, is a source of exquisite pleasure to herself, and of gratification to all connected with her.

The following table shows how the inmates were occupied during the year 1839:—

	Twine.	Baskets.	Mattresses.	Mats.	Rugs.	Weaving.	Knitting and Netting.	Spinning and Winding.	Total.
Men	11	9	1	1	1	13	...	...	36
Boys	6	2	...	...	...	3	8	...	19
Women	...	...	...	...	...	...	...	8	8
Girls	...	...	...	...	...	...	17	...	17
Porters	...	...	...	...	...	...	...	...	2
									82

Thus the manufactory consists of seventy blind people, and twelve not blind, viz. five men, six wheel-boys, and one woman; the wages of the latter being chargeable on the different branches of the manufacture in which they are engaged.

Sales for the Year 1839.

	£	s.	d.
Twine	610	10	9
Baskets	619	2	6
Mattresses	115	2	2
Baked Hair	85	8	5
Door-mats	155	8	5
Rugs	12	7	0
Knitting	163	4	7
Sacks for Grain	1,412	9	9
Hair Friction Mats	20	11	0
Nets for Walls	13	3	3
	£3,207	7	10
Expense of Superintendent, Matron, Teachers, &c.	199	11	8
Wages	910	4	11
Premiums	54	8	10

The males are on piece-work, and are employed ten hours per day; but when any particular articles are wanted, they are permitted to work twelve hours. None of the females who are not attending classes work more than seven hours in summer and six in winter. Those attending classes work three hours each day, and none of them more than two hours at a time.

A Comparative View of the State of Crime in London, Dublin, and Glasgow. By Captain MILLER.

Cities.	Year.	Estimated Population.	No. of Persons taken into Custody or charged with offences.	No. of Offenders in proportion to the Population.	Estimated Extent of Police Force.	No. of Inhabitants to each Police Officer.
London, within the Metropolitan Police District	1839	1,600,000	65,965	1 in 24¼	4500	355
Dublin, within the Metropolitan Police District	1839	300,000	45,682	1 in 7	1170	256
Liverpool and Suburbs	1838	265,000	16,689	1 in 16	600	442
Glasgow, within the City Police Bounds	1839	175,900	7,687	1 in 22¾	223	784

On the comparative Vital Statistics of Edinburgh and Glasgow. By Mr. WATT.

The proportion of marriages to the population in Edinburgh and Leith is as 1 to 144·449, or 0·692 per cent. In Glasgow the proportion is as 1 to 124·942, or 0·800 per cent. The number of deaths under twenty years of age in Edinburgh, in 1839, was 43·060 per cent. of the whole number of deaths; while in Glasgow the proportion was 62·312 per cent. In Edinburgh the proportion of deaths to the population was as 1 to 45·435, or 2·200 per cent.; in Glasgow the proportion was as 1 to 36·146, or more than 2·766 per cent. The deaths of children under five years of age are, in Edinburgh, 1 to 141·598 of the population; in Glasgow they amount to 1 in 72·014: in Edinburgh they are less than one-third of the whole number of deaths, in Glasgow more than one-half. From the imperfect state in which the registers of births are kept in Scotland, Mr. Watt declared that no reliance could be placed on the existing data of comparison; and the same remark, though in a less degree, extends to the registration of the causes of death, as data for the statistics of disease.

On the Vital Statistics of Glasgow. By Dr. COWAN.

Dr. Cowan exhibited a variety of tables, illustrative of the Meteorology and Statistics of Glasgow. He also exhibited a map of Glasgow, coloured, to show the state of the districts in relation to fever. From the table of marriages, it appeared that their proportion to the population, though always high, is fluctuating, depending on the state of trade and the prices of provisions. The extremes are to be found in 1825, remarkable for prosperity, when they amounted to 1 in 83·98; and in

1837, a year of destitution, when they fell to 1 in 120·76. From the table of births, it appeared that the ratio of males to females was as 22 to 20, a proportion much above that of any country in Europe. In 1831 the proportion of still-born was 1 in 14·49, a remarkable fact, as the ordinary average is about 1 in 20. The tables of deaths gave the mean annual mortality in Glasgow from 1822 to 1830, both inclusive, as 1 in 38·275; and from 1831 to 1839 as 1 in 31·896. The deaths under five years of age, for the nine years ending in 1830, were 42·91 per cent.; and for the same period ending in 1839, they were 43·32 per cent. It also appeared that the rate of mortality generally in Glasgow had increased during the last nine years, which was attributed to the increase of population beyond the suitable means of accommodation, the fluctuations of trade, &c. The number of deaths from smallpox was very great, amounting to 406 in the year 1839. The prevalence of epidemic disease was illustrated by several tables, from which it appeared that their advance had been slow, unless when extreme destitution prevailed.

On the Population, Trade and Commerce of the City of Glasgow. By Dr. Cleland.

The following are extracts:—

Increase of the Population, Revenue, &c. of Glasgow.

" *Population.*—In 1801 the population, according to the Government census, was 83,769, and in 1840, according to the three subsequent decennial returns, including the nine years from 1831 to 1840, the population amounted to 271,656, showing an increase in 39 years of 187,887 souls—a rate of increase, it is believed, unprecedented in this country.

" *River Clyde.*—In 1800 the revenue of the River Clyde was 3319*l.* 16*s.* 6*d.* In 1839 it amounted to 43,287*l.* 16*s.* 10*d.*, being an increase during 39 years of 39,968*l.* 0*s.* 9*d.*

" *Shipping in Glasgow.*—In 1651, a Committee of the Scotch Parliament appointed Commissioner Tucker to report on the Revenue of the Excise and Customs in Scotland, who stated that there were 12 vessels belonging to Glasgow; that the aggregate tonnage amounted to 957 tons. In 1840 the house of Messrs. Pollock, Gilmour and Co., of this city, who are engaged chiefly in the North American timber trade, are owners of 21 ships, register 12,005 tons, navigated by 502 seamen. The house has eight different establishments that ship annually upwards of six millions cubic feet of timber, to cut and collect which, and to prepare it for shipment, requires upwards of fifteen thousand men, and six hundred horses and oxen in constant employment.

" *Steam Vessels.*—On the 1st of January 1812, there was only one steam vessel in Europe, the Comet of Glasgow, of 30 tons burthen, with an engine of three-horse power. Now almost every river teems with them. It appears from the Parliamentary Steam Vessel Inquiry, that on 11th February 1839, there were 766 steamers connected with

the United Kingdom. Including the four North American mail steam-packets, the steam tonnage of Glasgow, in 1840, may be estimated at 13,491 tons.

"*Custom House.*—In 1812, the custom duties collected in Glasgow amounted to 3124*l.* 2*s.* 4½*d.*; and in 1839 to 468,974*l.* 12*s.* 2*d.*, being an increase during 27 years of 465,850*l.* 9*s.* 11½*d.*

"*Post Office.*—In 1810, the revenue of the Glasgow Post-office amounted to 27,598*l.* 6*s.*; and in 1839 to 47,527*l.* 7*s.* 7*d.*, being an increase during 29 years of 19,929*l.* 1*s.* 7*d.*

"*Supply of Water.*—Prior to 1806, the city, comprehending the ancient royalty alone, was supplied by about 45 public and private wells. As some of these were frequently dry, and others contained water of a bad quality, it may be near the truth to take the average supply of each well at 120 gallons of useful water, thus making the aggregate supply of 5400 gallons per day. The Glasgow and Cranstonhill Water Companies, now incorporated by Act of Parliament, produced, in 1840, 8,218,000 imperial gallons. The revenue of these two companies, for 1836, amounted to 25,302*l.* 13*s.* 9*d.*, and they laid out in conveying water from the Clyde to the city the sum of 349,808*l.*"

The population in 1831, when the last census was taken, consisted of 163,600 Scotch, 35,544 Irish, 2919 English, and 353 foreigners.

The following is a description of the householders:—

"Married men, 30,032; Widowers, 1790; Bachelors, 1437; Male Householders, 33,259; Widows, 6824; Spinsters, 1882; Female Householders, 8706; Total Families, 41,965.

"The births, including 471 still-born, being 6868, and the population 202,426, there is one birth for every 29·47 persons.

"The marriages being 1919, there is one marriage for 105·48 persons.

"The burials being 5185, there is one burial for 39·04 persons.

"The number of families being 41,965, there are 4·82 persons to each family.

"The births being 6868, and the number of marriages 1919, there are 3·57 births to each marriage."

On the State of Crime within the Suburban Districts of Glasgow. By Mr. Rutherglen.

The supposed population of Calton, in September 1840, was 28,210. The police force consists of 1 superintendent, 6 serjeants, 14 watchmen, and three lamp-lighters, who also act in the capacity of scavengers. Expenses of the establishment for the year ending September 1839, including salaries, wages, lighting, cleaning, Bridewell, and other charges, 1324*l.* 17*s.* 11½*d.*

Extent of Crime.—During the year ending 30th September 1839, 2601 persons were charged with crimes, offences, and with contravention of police regulations. Of this number 1799 were found guilty, and sentenced—208 to confinements of various durations

in the Burgh Bridewell, and 1591 to pay fines, which amounted to 207*l.* 2*s.* 8*d.*; the remainder were disposed of as follows:—56 were transferred to the Sheriff, 63 to the Justices, 5 to the Glasgow police, 1 to the Lunatic Asylum, 5 to the House of Refuge, 430 were reproved and admonished, and 242 were dismissed. The criminal population is less by one-half than it was in 1835–6; and although in 1839 there were 2601 charged, and 1799 convicted, it is proper to mention that the same person has been charged and convicted as often as *three* times with petty thefts, and with other crimes and offences *twenty* times in the course of the year; and it is not in one, but in many cases, that this has occurred.

House of Refuge.—The establishing of this Institution has had a beneficial effect in the repression of crime, by withdrawing from the streets of the city and suburbs several hundreds of destitute boys, who lived almost by thieving alone; and it is not an over-estimate to say, that 250 of them stole property averaging 1*s.* each per day when loose upon society.

Pawnbrokers.—There are two licensed within the burgh.

Brokers.—In 1835 there were 120 brokers in Calton; in 1839 they were reduced to 88, and the following is their classification:—

Dealers in old metals	4
Furniture Brokers	16
Dealers in old weaving utensils	4
Dealers who buy all their goods at public sales	4
Dealers in old clothes	4
Bundle-brokers, or "Wee Pawns"	56

Publicans.—There are at present 119 licensed publicans within the police bounds; and during the year ending September 1839, 38 cases were brought before the magistrates of disorderly houses.

Lodging Houses—are generally of an exceedingly wretched description, but the Police Act gives powers for the regulating of those houses.

Health.—The state of health is anything but satisfactory. Fevers, pulmonary complaints, rheumatism, and influenza prevail.

On the State of Crime in the Suburban Burgh of Anderston. By Mr. FINDLATER.

From the tables produced, it appeared that the cases brought before the magistrates of the burgh of Anderston were of the most trivial kind. Last year there was not one charge of robbery; out of 101 cases of theft, only one was sent to the sheriff, while 62 petty cases were remitted to the justices. The number of cases brought before the police court for the year ending 21st September 1840, were 1205, and the number of persons 1900, among which there were about 300 for dirty closes alone, besides a corresponding number for exposing articles outside of shops, encumbering streets, and other minor contraventions of the Police Act, and about a fourth of the remainder are offenders from the

city. The cases were disposed of as follows:—879 were fined in various sums, amounting to 190*l.*; 64 were confined for short periods in the police cells; 1 sent to the sheriff; 75 to the justices; 1 to another town; 1 escaped; 2 policemen discharged; 4 reproved, and 177 dismissed. Total, 1205.

On the State of Crime in the District of Gorbals. *By Mr.* Richardson.

	Gorbals.	Glasgow.
Population	65,000	175,000
Average assessment for each inhabitant	1*s.* $1\frac{1}{2}$*d.*	2*s.* $2\frac{1}{2}$*d.*
Number of offenders brought before magistrates	4,009	7,687
Proportion to the population	1 in $16\frac{1}{4}$	1 in 22
Expense to the public for each offender	9*s.*	1*l.* 5*s.*
Number of persons admonished	903	1,879
Number convicted	3,106	6,570
Reported value of property stolen	500*l.*	7,653*l.*
Amount of property recovered	300*l.*	1,260*l.*
Number of superior officers	3	12
— ordinary officers	8	59
— watchmen	29	149
— criminal officers	1	6
Cost of the above department of police	1,833*l.*	9,568*l.*

On the State of Education in the Borough of Kingston-upon-Hull. *By the* Manchester Statistical Society.

The present report contains the result of an inquiry carried on in the months of March, April, May, and June, 1839. The whole of the facts were collected by the same agent to whom the previous investigations of the Society of a similar kind had been intrusted, and of whose perseverance and accuracy the Society have had ample experience.

The object was twofold: first, to throw light upon the physical, moral, and religious condition of the great body of the inhabitants; and secondly, to ascertain the state of education, both in its results, as apparent in the acquirements of the people, and with respect to the use which was made of the existing means of education for the younger portion of the community. In regard to the Sunday schools, very complete information was obtained throughout the whole borough of Hull, containing a population of at least 52,000 inhabitants. The township of Kingston-upon-Hull, containing a population of 37,885, was examined from house to house; it presents a remarkable contrast with the large towns visited in Lancashire in the character of the dwellings of the working classes. It was found that of 8757 dwellings visited, only 15 were cellars, and their inmates amounted altogether to 44 persons. In Liverpool nearly one-fifth, and in Manchester and Salford about one-tenth of the working classes were found to be living in cellars, while in Hull there are only 15 for every 10,000. The

system of living in lodgings is also less extensive in Hull, and there are only 6239 heads of families occupying houses, as distinguished from chambers, out of the total number of 8757 heads of families; whereas in a corresponding table for the township of Pendleton, near Manchester, about nine-tenths of the heads of families are recorded as occupying houses. Under 10 years of age, only 43 children were found at work in Hull, while in Pendleton, with one quarter of the population, there were 37. Between the ages of 10 and 15 there were twice as many at work in Pendleton in proportion to the population, and between 15 and 21 years of age the proportion was also somewhat larger. One-third of the adults whose occupation was recorded in Pendleton were females, as also were about nine-twentieths of the minors at work; while in Hull little more than one-third of the minors at work were females, and not quite one-fourth of the adults. The proportion of persons under 21 years of age is smaller in Hull than in Pendleton, and there is also less employment for children and females in Hull. The relative proportion of the sexes does not differ materially. But the most remarkable contrast between Hull and the Lancashire towns appears in the country from which the people spring. In Hull above 95 per cent. of the heads of families were English, only 2 per cent. Irish, and $1\frac{1}{2}$ per cent. Scotch; and taking the whole adult population, the proportions are—

English	95·08	per cent.
Irish	2·24	—
Scotch	1·36	—
Foreigners	·84	—
Welsh	·48	—
	100·00	

In Liverpool and Manchester the Irish form no inconsiderable portion of the whole working class. In Manchester more than one-sixth of the heads of families amongst the labouring population were Irish; and taking Manchester and Salford together, the Irish constitute one-sixth, the Welsh one-thirtieth, and the Scotch one-fiftieth of the whole, while in Liverpool the proportion of Welsh is much greater than in Manchester. Among the day schools of Hull the agent remarked the existence of a large number of charity schools. There were two proprietary schools, one chiefly supported by churchmen, the other by dissenters. The poor-house schools appeared both clean and orderly, and were conducted on a system somewhat assimilating to that of Dr. Bell. The infant schools, of which there were several, were of comparatively recent establishment. So far as the opportunity was afforded for observing the condition and management of the dame schools, they appeared to be equal to the same class of schools in Birmingham, and superior to those of Liverpool and Manchester. They were generally tolerably clean, and not so confined as in the large manufacturing towns. The following statement of the proportion of day scholars to the total population has been prepared, showing, by comparison with the numbers in other districts previously examined, that the result for

Hull closely approximates to York and Rutlandshire, which have been the most favourable examples hitherto brought to light by the inquiries of the Society. The ascertained cases, in a population of 32,500, are here taken, and they furnish a proportion of

16·45 per cent. of the total population attending day or evening schools.
3·33 per cent. were under 5 or above 15 years of age; leaving, therefore,
13·12 per cent. as the proportion of the total population, being children between the ages of 5 and 15, then in attendance at day schools.

In Hull it was ascertained that the proportion of individuals of this age was 21 per cent. of the entire population; it is therefore proved that 7·88 per cent., or rather more than one-third of the children between 5 and 15, were not in attendance at the day schools. The actual number counted, corresponding with this proportion, was 2573, of whom 306 were between the ages of 5 and 10, and 1566 between 10 and 15.

58 were under instruction at home.
1872 had been at day schools at some period.
238 were, or had been, at Sunday school *only*.
405 had never been at any school, and appeared not to have been instructed at home.
——
2573

The following table, drawn up from earlier reports of the Society, in York, Rutlandshire, Liverpool, and Manchester, shows that the proportion of children *not* in attendance at school, is smaller in Hull and York than in Liverpool and Manchester:—

Proportion of Children attending Day and Evening Schools, as compared with the total Population.

Per-centage of children attending.	York in 1836. Population estimated, 28,000.	Rutlandshire in 1838. Population estimated, 20,000.	Liverpool in 1835 and 6. Population estimated, 230,000.	Manchester and Salford, 1834 and 5. Population estimated, 255,000.
Day schools supported exclusively by the scholars.........	7·18	6·77	6·70	7·33
Ditto supported or assisted by the public	9·63	8·05	5·87	2·35
Evening schools	0·15	0·37	0·24	0·78
Total.........	16·96	15·19	12·81	10·46
Proportion to the total population of day and evening scholars under 5 and above 15 years of age.....................	2·74	3·06	2·14	1·95
Proportion to the total population of day and evening scholars between 5 and 15 years of age	14·22	12·13	10·67	8·51
Proportion of children between 5 and 15 years of age estimated not to be in attendance at day or evening schools, about	$\frac{2}{5}$	$\frac{1}{2}$	$\frac{5}{9}$	$\frac{2}{3}$

The number of adults who can both read and write and cipher, amounts to nearly two-thirds of the ascertained cases, of whom at least nine-tenths can read; while at Pendleton, in Lancashire, only about one-third of the ascertained cases amongst the adults were able to read, write and cipher, though nearly the same proportion as in Hull were able to read only. In Pendleton, 405 adults out of 4855 ascertained cases had never attended a day school; but some few of these had acquired the power of reading, and even of writing. In Hull, 417 only, out of 14,526 ascertained cases, had never been at a day school, and none of them had learned even to read. Those who could read were in the proportion of fifty-five in Pendleton to sixty in Hull; those who could write were twenty-four in Pendleton to thirty in Hull; and those who could cipher were twelve in Pendleton to twenty-two in Hull.

An attempt was made in Hull to ascertain the age at which the children had been taken away from school, and the information was obtained in about three-fifths of the cases. The result obtained on this subject shows, that out of about 2798 children, only

131 had remained at school after reaching the age of 13.
1108 left at 12 and 13 years of age.
964 „ 10 and 11 „
595 left before 10; about one-half of whom had been removed before they were 9.

Hardly any of those who had left school before the age of nine had acquired any knowledge of figures or of writing; and for ninety of them who were able to read, there were as many more who did it very badly, and above 120 who could not read at all. Out of 5250 children who were at school at the date of this inquiry, 305 cases occurred in which no satisfactory account could be obtained as to the regularity of attendance; and the attendance in 997 cases was admitted to be very irregular; so that in 3948 cases alone can it fairly be assumed that the children were deriving from their attendance the whole of the benefit, little or great, which the schools were capable of affording. In the case of the children who had left school, the result was still more unfavourable; out of 4097 ascertained cases, only 2426 had attended regularly, and 1671 irregularly; 628 cases occurred in which no satisfactory information on this point could be obtained. Taking the whole of the minors who either had been, or were, at the time of the inquiry, at school, 6374 were stated to have attended with regularity, and 2668 irregularly; and in 943 cases no information on the subject could be obtained. The number of children who could read with ease corresponds very nearly with the number of those who had been regular in their attendance at school. The former amounted to 6166, the latter to 6374, and the number of those who could write and cipher was much smaller—the number of those who could write amounted to 3038, and the number of those who could cipher to 2207. It may with tolerable certainty be inferred from the Hull tables, that there is the greatest regularity of attendance between the ages of eight and eleven.

Amongst the number of parents whose children were of an age to

be at school, but who were not attending any, 133 gave the following as reasons for their non-attendance:

35 Poverty.
32 Irregularity of their employment.
19 Want of decent clothing.
6 The children living with their parents in boats on the river.
13 Ill health of parents.
15 Death of the father.
2 Desertion of the father.
11 Largeness of the family.
133

Of the 4735 minors who, at the date of this inquiry, had completed their education, such as it is, 823 were unable to read a whole sentence; 1870 were unable to write; and 2282 unable to cipher. In the same class of children, those who had been irregular attendants at school amounted to 1671.

In a classification of the answers given by the heads of families, as to their religious denomination, no less than eighteen different Christian sects were enumerated; and ten of these support their separate Sunday school.

Proportion per cent. of the Sunday Scholars to the total Population.

	Hull, 1839*.	Bury, 1835*.	Manchester & Salford, 1834-5*.	Rutlandshire, 1838*.	Leeds, 1836†.	York, 1836*.	Birmingham, 1838‡.	Liverpool, 1835-6*.
Church of England	6·11	7·67	5·11	11·60	5·03	6·10	2·54	2·75
Roman Catholic ...	0·31	0·78	1·76	——	8·88	——	0·18	0·30
Dissenters	6·66	12·67	9·97	4·38		5·91	6·59	3·63
Total...	13·08	21·12	16·84	15·98	13·91	12·01	9·31	6·68

Proportion per cent. of the Sects to the total number of Sunday Scholars.

	Hull, 1839*.	Bury, 1835*.	Manchester & Salford, 1834-5*.	Rutlandshire, 1838*.	Leeds, 1836†.	York, 1836*.	Birmingham, 1838‡.	Liverpool, 1835-6*.
Church of England	46·75	36·33	30·33	72·56	36·13	50·79	27·24	41·11
Roman Catholic ...	2·35	3·[illegible]	10·46	——	63·87	——	2·02	4·56
Dissenters	50·90	60·[illegible]0	59·21	27·44		49·21	70·74	54·33
Total...	100·00	100·0	100·00	100·00	100·00	100·00	100·00	100·00

On Pawnbroking in Ireland, and on the beneficial results which had followed from the establishment of a Mont de Piété, in connexion with a Loan Fund, at Tanderagee. By Mr. Porter.

"In order to ascertain as nearly as possible the amount of business which is done throughout Ireland, I consider that one whole county, that of Armagh, in which I reside—one large trading town, such as Belfast—and the metropolis of Ireland, would furnish data on which to calculate, if necessary, the pawnbroking business of the whole kingdom. I therefore deposited at every pawnbroker's in these places an

* Inquiries conducted by the Manchester Statistical Society.
† Inquiry conducted by the Town Council of Leeds.
‡ Inquiry conducted by a Committee in Birmingham.

article of clothing, and received duplicates or tickets, each bearing a number on it, showing the order in which articles are received and registered. In seven days after I deposited another article of dress at each pawnbroker's as before, and received in like manner duplicates or tickets, and in a few cases, where there was some doubt as to the numbers written on the tickets, which are not always very legible, I deposited a third article. The amount of money lent is calculated, on an average, at 3*s.* on each article, except in Dublin, and there it is found to be about 4*s.*"

Mr. Porter then read the following table:—

City or Town.	Number of Pawnbrokers.	Number of Pawns in Twelve Months.	Amount lent in Twelve Months at 3*s.* each Pawn.	Amount charged in Pence for Duplicates.	Profit after Printing Duplicates, and deducting 6 per cent. for Capital, and 6 per cent. for Stock.	Population.
Armagh	4	97,980	£14,697	£408 5 0	£1,170 3 10	10,518
Lurgan............	3	43,440	6,516	181 0 0	516 3 7¾	2,842
Newry, part of...	2	40,680	6,102	169 10 0	483 7 1¾	See next table.
Tanderagee	1	15,540	2,331	64 15 0	184 13 8½	1,559
Portadown	1	14,940	2,241	62 5 0	177 10 9½	1,591
Markethill	1	9,660	1,449	40 5 0	114 15 6½	1,043
Total in the C. of Armagh	12	222,240	£33,336	£926 0 0	£2,646 14 2	
Newry, whole of	7	120,000	£18,000	£500 0 0	£1,425 15 6	13,135
Belfast............	35	737,280	110,592	3,072 0 0	8,760 19 1½	67,388
Dublin............	42	3,820,200	764,040	15,917 10 0	56,107 11 3	265,316

The poor of the county of Armagh, therefore, pay for duplicates nearly one thousand pounds annually, the poor of Newry five hundred pounds, the poor of Belfast above three thousand pounds, and those of Dublin near sixteen thousand pounds. The paupers' pence charged by the pawnbrokers, in the county of Armagh, in twelve months, exceeded the county grants to dispensaries by the sum of 132*l.* 17*s.* 6*d.*

		£ *s.* *d.*
Paupers' pence being....................	£926 0 0	
County grants to dispensaries............	793 2 6	—132 17 6

And the estimated profits of the pawnbrokers within the county of Armagh, after paying for the printed tickets, and deducting six per cent. for interest on their capital, exceed the whole of the Grand Jury presentments for charitable purposes by 260*l.* 10*s.* 4*d.*

The profits being		£2,646 14 2
Grand Jury presentments, viz.		
To 15 Dispensaries....................	£793 2 6	
County Infirmary	593 3 1	
District Lunatic Asylum...............	999 18 3	
	£2,386 3 10	—260 10 4

"Having succeeded in proving to the gentry, to the clergy of all persuasions, and to the merchants of the town of Tanderagee, in which I reside, that the Mont de Piété system of pawnbroking would present a mitigation of evil, they co-operated with me in the establishment of an institution, embracing a charitable pawn-office, a loan-fund, and a bank for savings, all under one administration, managed by the same board of directors, with whom I have the pleasure of acting as one of the honorary secretaries." The following is an abstract of the result of the operations of the Tanderagee Mont de Piété:—

	No. of Pawns deposited.	No. of Pawns released.	Amount lent on Pawns.			Amount received on Pawns released.			Interest received on Pawns released.		
1839.			£	s.	d.	£	s.	d.	£	s.	d.
For nine months, Jan. to Sept.	12,312	8,521	1,500	6	0	1,023	9	8	76	0	$2\frac{1}{2}$
For three months, Oct. to Dec.	2,900	3,020	422	8	4	395	4	0	34	15	$3\frac{1}{2}$
Total for twelve months...	15,212	11,541	1,922	14	4	1,418	13	8	110	15	6
1840. For nine months, less two weeks, to the present period	6,523	6,698	864	9	11	981	5	5	104	11	0
									Increase of interest, the Releases being greater than the Pawns.		
Decrease on the nine months of 1840, less two weeks, compared with nine months of 1839	5,789	1,823	635	16	1	42	4	3	28	10	$9\frac{1}{2}$

In nine months of 1839, 11 out of 16 articles were released, and 3791 articles remained in store, over and above the number of articles released; and in 1840, up to the present period, 175 articles were released, more than the whole number pawned.

LOAN FUND DEPARTMENT.

	Number of Loans.	Amount Lent.	Weekly Instalments.			Interest, and Fines received.		
1839.			£	s.	d.	£	s.	d.
For nine months, Jan. to Sept....	3,745	15,286	15,107	11	11	608	2	5
For three months, Oct. to Dec....	1,011	4,141	4,247	11	2	178	11	2
Total for twelve months......	4,756	19,427	19,355	3	1	786	13	7
1840. Nine months, less two weeks, to present period	1,980	8,150	8,303	6	7	291	8	4
Decrease on the 9 months, less 2 weeks, of 1840, compared with 9 months of 1839 ...	1,765	7,136	6,804	5	4	316	14	1

SAVINGS' FUND DEPARTMENT.

	Lodged.	Withdrawn.
Savings in nine months of 1838	£688	£408
— in nine months of 1839	994	594
— in twelve months of 1839	1303	943

Mr. Porter gave an account of a Mont de Piété since established at Portadown; and mentioned that he had been last year successful in establishing one in Belfast. Mr. Porter then presented estimates of the extent of business carried on by the licensed and unlicensed pawnbrokers of Glasgow: viz. by the licensed pawnbrokers, loans, 149,674*l.*; and by the unlicensed pawnbrokers, above half a million of money, the latter sum at an interest of 433*l.* 6*s.* 8*d.* per cent.

Mr. Bryce of Belfast, stated that the Ulster Statistical Society had made such progress in their inquiries into the state of education and the condition of the linen trade in the North of Ireland, that they would be able to present the results in a complete form at the next meeting of the Association.

On the Bill Circulation of Great Britain By Mr. LEATHAM.

Having, through Lord Morpeth, obtained a return of the number of stamps issued from 1835 to 1839 inclusive, Mr. Leatham based his calculations on the supposition that each bill was circulated for half the sum which the stamps would cover, which was considerably under the amount. From the experience of his own bank, compared with that of the principal discount offices in London, he had found that the average date of bills, including foreign and inland, was three months. He then took the whole stamps for a year, and divided them by four, which gave the amount circulating at one time. By a similar induction, he had estimated foreign bills at one-sixth of the English, though the proportion was rather greater; and he had taken the same average for Irish bills in the years where no official returns had been made. He then exhibited the following statement relating to the bill circulation of Great Britain and Ireland, during the years under-mentioned:—

	1815.	1824.	1825.	1826–7.
	£	£	£	£
Bill Stamps for Great Britain, creating the sum	477,493,100	232,429,800	260,379,400	207,347,400
Estimated Irish Bills	79,582,183	38,738,300	43,396,566	34,557,833
Foreign Bills	92,845,880	45,194,683	50,629,327	40,317,072
Total	649,921,163	316,362,783	354,405,293	282,222,305
Average amount in circulation at one time......................	162,480,290	79,090,695	88,601,323	70,555,576

The following is a similar return for the last five years :—

	1835.	1836.	1837.	1838.	1839.
	£	£	£	£	£
British Bills	294,775,269	355,288,900	333,268,600	341,947,400	394,203,000
Irish Bills	51,109,061	59,155,607	54,179,165	54,359,464	55,615,722
Estimated amount of Foreign Bills	57,914,721	69,420,406	65,012,080	66,500,577	75,479,120
Bills created by Bankers compounding for Stamps	1,604,000	2,078,560	2,624,600	2,696,600	3,196,000
Total.........	405,403,051	485,943,473	455,084,445	465,504,041	528,493,842
Average amount in circulation at one time	101,350,762	121,485,868	113,771,111	116,376,010	132,123,460

On the State of Education and Crime in England and Wales. By Mr. Joseph Bentley.

The author exhibited, in a tabular form, the proportion of persons to one school, one bookseller, one public library, one Mechanics' Institute, and one ale-house, in the several counties of England, explaining that he had collected these data while engaged in the compilation of Pigot's Directory. He had taken the criminal statistics from the parliamentary return of committals, and the amount of population from the last decennial census. He entered into a very minute comparison between the town of Dudley and the city of Worcester, from whence he inferred that education was demonstrably a restraint on crime.

Dr. W. Cooke Taylor read an abstract of a paper communicated by Mr. Saxe Bannister, 'On the Population of certain parts of Africa.' The object was to show, that the function of vitality was much higher in the American settlement of Liberia than in Sierra Leone and the Anglo-African colonies; and also that the natives more readily came to the Americans than to the British.

On the Application of Statistics to Moral and Œconomic Science. By Dr. Chalmers.

On the Pauperism of Glasgow. By Dr. Chalmers.

Illustrations of the Practical Operations of the Scottish System of the Management of the Poor. By Dr. Alison.

The discourses of Dr. Chalmers and Dr. Alison contained frequent references to statistical data, but the enumeration of these would be of little service without a full statement of the arguments they were intended to support.

On the excess of Population, and on Emigration as a Remedy for it, in the Highlands of Scotland. By Dr. ALCORN.

On the Population of Scotland. By Mr. WILSON.

On the Libraries of Germany. By Professor ADRIAN.

On the Parish of Dunfermline. By the Rev. P. CHALMERS.

MECHANICAL SCIENCE.

On the Temperature of most effective condensation in Steam Vessels. By J. SCOTT RUSSELL.

Much has been said regarding the perfection of the vacuum formed in the condenser of a steam-engine, especially a marine engine. It is a fact of great importance, and it is the result of theory, established on incontrovertible truth, and confirmed by experiment and by practice, that a vacuum may be too good, and become a loss instead of a gain. The truth is simply this, and should be known to every engineer: *If the barometer stand at* $29\frac{1}{2}$ *inches, the standard of this country, the vacuum in the condenser is* TOO GOOD *if it raise in the barometer more than* 28 *inches of mercury.* The following is a simple proof of this doctrine, divested as far as possible of a technical form, and put in the shape of an inquiry into the best state of a condenser:—

Let $t =$ the caloric of water of $1°$;
$c =$ the constituent caloric of water in the state of steam;
$e =$ the total force of steam in the boiler, in inches of mercury; and
$x =$ the elastic force of steam at the temperature of best condensation, which we seek to discover.

Then, from the law which connects the elastic force of steam with

temperature, it follows that, in case of maximum effect, or the temperature of best condensation,

$$\frac{t}{c} = \frac{x}{e}, \text{ that is, } x = \frac{e}{c}.$$

Now c is 1000; and if the steam in the boiler be at 5 lbs. above the atmosphere, or if $e = 40$ inches of mercury, and $t = 1$,

$$x = \frac{40}{1000} = 0{\cdot}04.$$

Again, if the steam be at $7\frac{1}{2}$ lbs. = 45 inches,

$$x = \frac{45}{1000} = 0{\cdot}045.$$

Again, if the steam be at 10 lbs. = 50 inches,

$$x = \frac{50}{1000} = 0{\cdot}05.$$

Hence we find, that the best elasticity or temperature in the condenser depends on the elastic force of the steam in the boiler.

With steam of 5 lbs. in the boiler, the elasticity of maximum effect in the condenser is 93° Fahr., and the best vacuum on the barometer is 28.

With steam of $7\frac{1}{2}$ lbs. in the boiler, the elasticity of maximum effect in the condenser is 95°, and the best vacuum on the barometer is 27·8.

With steam of 10 lbs. in the boiler, the elasticity of maximum effect in the condenser is 97°, and the best vacuum on the barometer is 27·6.

In like manner it would be found, that with steam of 50 lbs. in the boiler, worked expansively, as in Cornwall, the best vacuum in the condenser would be about 26· on the barometer.

It is hoped, therefore, that engineers will not in future distress themselves at finding the vacuum of their condenser much less perfect than the vacuum of others who have obtained 30 and $30\frac{1}{2}$ inches at so great a loss of fuel and power. To obtain a vacuum of $29\frac{1}{2}$, with the weather glass at 29·75, and steam at $7\frac{1}{2}$ lbs., would be to sacrifice four horses' power out of every hundred. In a day when the barometer is as low as $28\frac{1}{2}$ inches, the vacuum in the condenser would indicate 26·8. In speaking of the vacuum in the condenser, it would save much ambiguity to indicate the elasticity merely of the steam in the condenser; thus, if the barometer stand without at $29\frac{1}{2}$, and the barometer of the condenser at 28, it might be stated that the steam in the condenser stands at $1\frac{1}{2}$, being the point of the maximum effect. The indication would convey at all times more precise information.

Mr. Russell stated that the President had just put into his hands a communication in French on this subject from M. Barnes. Instead of a jet playing inside the condenser, M. Barnes allows it to rush in suddenly, and then stops it by a slide-valve.

Additional Notice concerning the most Œconomical and Effective Proportion of Engine Power to the Tonnage of the Hull in Steam Vessels, and more especially in those designed for long Voyages. By J. SCOTT RUSSELL.

After describing the unsettled state of opinion and practices on this subject, Mr. Russell entered into a general examination of the subject, from which the following are extracts :—

"We may now proceed to investigate the question of best proportion, or the point where the attainment of high speed is accompanied by absolute saving of fuel, as compared to lower velocity.

"We merely take it for granted, that the speed through the water will be nearly as the square root of the power, according to the general law of the resistance of fluids; that the resistance offered by bad weather or adverse winds has been ascertained, and is determined on a particular station; that is, that it is known that on a given station, a given vessel, with a given power, makes a voyage in adverse circumstances in, suppose, double the time of her most prosperous voyage; (say her most prosperous voyage in 14 days, and her adverse voyage in 24 days, being a retarding power of 10 days out of 24;) we take this retardation of ten days as the measure of the retarding power of adverse weather in the given circumstances.

Let h be the power, v the velocity, f the fuel consumed, t the time in good weather .... Let..........v'..........., f'.........., t' in bad weather	In a given vessel on a given station.
Let h' be the power, v'' the velocity, f'' the fuel consumed, t'' the time in good weather.......... Let..........v'''.........., f''' ...., $t\,'$ in bad weather	In another vessel of greater on the same station.

Also, let r represent the consumption of fuel per horse-power per hour,
And ... s the length of the voyage or distance performed."

By investigating, Mr. Russell obtains the general formula—

$$x = 2\,h\,\frac{v^2 - v'^2}{v^2} - \text{(A)},$$

and deduces the following consequences :—

"It appears that a vessel has its power in the most œconomical proportion to its tonnage, on a given station, when its worst voyage does not exceed the time of its best in a greater proportion than $\sqrt{2}$ to 1, that is, than 14 to 10, or 7 to 5.

"It further appears, that the consumption of fuel in the worst voyage will not exceed that of the best voyage in a greater proportion than 10 to 7; that is to say, for 70 tons of fuel burnt on a good voyage it will not be necessary to carry more than 100 tons in order to provide against the worst.

"Let us take as example a Transatlantic steam-ship, which has a proportion of one-horse power to four tons of capacity, her unfavour-

able voyage being between England and America 22 days, and her favourable voyage 14 days, being a comparative velocity of 7 and 11.

$$\text{Then } h' = 2h\frac{v^2 - v'^2}{v^2} = 2.\frac{121 - 49}{121.} = 2.\frac{72}{121}$$

$$= \frac{12}{10} \text{ nearly.}$$

Hence the power should be increased in the ratio of 6 to 5; that is to say, the engines at present capable of exerting a power of 500 horses should have been capable of exerting a power of 600 horses, and would in this case consume less fuel, as well as produce greater regularity and a higher velocity."

The following results also follow:—

"The vessel of less power burns 30 tons per day, performs the distance in 14 days, consuming 420 tons of coal in fair weather.

"The vessel of less power burns 30 tons, performs the distance in 22 days, consuming 660 tons of coal in foul weather.

"The vessel of greater power burns 36 tons, performs the distance in $12\frac{1}{2}$ days, consuming 468 tons in fair weather.

"The vessel of greater power burns 36 tons, performs the distance in 17·5 days, consuming 630 tons in foul weather, being a consumption of 64 tons less fuel, and performing the journey in $4\frac{1}{2}$ days less than the other.

"It is manifest, that the store of fuel carried in the vessel with less power must on all occasions be equal to the greatest consumption, that is, to at least 660 tons, whereas 630 tons will be sufficient for the vessel of greater power; and as in all vessels for long voyages coals carried are much more costly than the mere price of coals, or as the freight of the vessel is more costly than the fuel, coals carried are to be reckoned at least as expensive as coals burnt. Moreover, as the gain in time is $4\frac{1}{2}$ out of 22, being 25 per cent., it is plain that the vessel may be calculated to do the distance oftener in a year, because, as the time of starting must always be regulated, not by the shorter, but by the longest period of a voyage, $17\frac{1}{2}$ days in the one case stand in the place of 22 days in the other. As another example, let us take the case of a vessel calculated to stem the monsoon in the Indian Seas. A vessel of 600 tons and 200 horses, steaming in fair weather at the rate of 11 miles an hour, has been found to have her speed diminished by the monsoon to five miles an hour. What would be the best proportion of power in such circumstances?

$$h' = 2h\,\frac{v'^2\ v'^2}{v^2} = 2.\frac{11^2 - 5^2}{11^2}$$

$$= \frac{16}{10} \text{ nearly.}$$

"Hence we see that the power being increased in the ratio of 16 to 10, that is, engines of 320 horses power being substituted for those of 200, the speed on the quick voyage would be $12\frac{3}{4}$ miles an hour instead of 11, and the speed against the monsoons increased from 5 to 9

miles an hour, with a saving of coals amounting to 40 tons out of 320; and when it is remembered that the voyage for which 18 days would be required as continual allowance in the one case might always be calculated on as performed in 10 days in the other, the advantage is placed beyond all doubt. It appears, therefore, that for long voyages especially, there are great advantages in point of œconomy, certainty and speed, to be obtained by the use of vessels of a higher power than usual, and that in a given case the best proportion of power to tonnage may readily be determined from the rules already laid down. In regard to absolute or definite proportion, it may be stated as the result of the best vessels, that the proportion of power to tonnage should not be greater than one horse power to two tons, nor less than one horse to three tons; the greater proportion holding in the smaller, and the less proportion of power in the greater vessel."

Notice of Properties of the Catenary and Curves of Equilibration, with Tables for their Construction, contained in a Memoir entitled, "The Parallelogram Forces and Curves of Equilibration; together with Tables for their Construction, deduced from a Functional Equation. By William Wallace, *LL.D., &c., Emeritus Professor of Mathematics in the University of Edinburgh."*

The memoir in the Edinburgh Transactions here noticed, contains tables for the construction of the catenary, which are true to ten decimal places (the parameter being the unit); by these the co-ordinates of the curve, also its length, may be found to an extent of the curve and degree of accuracy beyond the wants of the civil engineer in actual practice. To secure accuracy, the tables have been stereotyped in an octavo size, and proofs of the plates carefully compared with the original calculations, which have been all preserved, and may be deposited with some public body.

It is intended in the course of the ensuing winter to re-publish the tables in an octavo form, accompanied with a Treatise on the *Catenary and Curves of Equilibration*; and to these will be added some other matters connected with the practice of civil engineering.

On a New Mode of Propelling Fluids, or an uniformly Propelling Wheel. By the Rev. J. Brodie.

In this communication the author gave an account of a uniformly propelling wheel for steam-boats, and directed attention to the proper form of the leaves of a propeller on the Archimedean principle. The contrivance for uniform propulsion consists of a number of vanes or float-boards, placed on a revolving axle, so that the plane of the float-boards forms an acute angle with the axle to which they are applied. They may be either fastened to the axis spirally, forming a sort of screw, or affixed circularly, forming a wheel.

This principle admits of various applications, and may be employed in propelling either with water or air.

On the Strongest form of Sea-borne Vessels. By Dr. FARQUHARSON.

The author stated in this communication the result of his attempt to determine the true form of the Ark of Noah, as given in the Hebrew text of Genesis, compared with the Greek Septuagint; and arguing that this form, though unfit for carrying sails, was excellent for flotation, stability and strength (being triangular in the cross section, with a flat base and angular top), suggests that the forms of sea-going steamers should be reconsidered and altered, with a view to these circumstances.

Mr. Evans delivered in a printed report "On Anthracite Pig-iron."

On the Turbine Water-wheel. By Professor GORDON.

The fundamental principle upon which the construction of the *Turbine-Fourneyron* is based, is that by which the maximum of useful effect is obtained from a given fall of water, depending on the relative velocity of the water and its recipient, which ought to be such that the water enters the wheel without shock, and quits it again without velocity. A notion of its construction may readily be formed, by supposing an ordinary water-wheel laid on its side, the water being made to enter from the interior of the wheel by the inner circumference of the crown, flowing along the buckets, and escaping at the outer circumference. Then centrifugal force becomes a substitute for the force of gravity. It was explained that the Turbine consists essentially of—

1. A reservoir, the bottom of which is divided into radial compartments by curved plates, serving to guide the water to take a particular direction of efflux.

2. A circular sluice, capable of nicety of adjustment.

3. The wheel with curved buckets, on to which, when the sluice was raised, the water entered at every point of the inner circumference, and flowing along the buckets, escaped at every point of the outer circumference. This latter is a characteristic feature in the Turbines of Fourneyron. Reference was made to the principal Turbines erected in France and Germany,—particularly to that at Inval, near Gisors, and those at Müllbach and Moussay, as illustrative of their use for falls varying from 9 inches to 10 feet. And again to those at St. Blasier, in the Black Forest, as instances of high falls,—the one being $70\frac{1}{2}$ feet, the other 345 feet; the one expending 5 cubic feet per second, the other 1 cubic foot per second; the one being 56 horse-power, the other very nearly 60 horse-power; the one giving an efficiency of upwards of 70, the other of upwards of 80 per cent. of the theoretical effect. A drawing of the latter was exhibited—full size. It is $14\frac{1}{2}$ inches diameter. Its extreme depth or *breast* is ·225 inch, or less than $\frac{1}{4}$. It makes 2200 to 2300 revolutions per minute. It serves a factory in which are 8000 water spindles, 34 fine and 36 coarse carding-engines, 2 cleansers, and other accessories.

The conclusions drawn by Morier from his experiments on these wheels with the brake dynamometer, or friction strap, are these:—

1. That Turbines are with equal advantage applicable for high and for low falls. 2. That their net useful effect equals 70 to 78 per cent. of the theoretical effect of the power. 3. That they may work at speeds varying from

$$n = \frac{3{\cdot}3\ V}{R} \text{ to } n = \frac{5{\cdot}6\ V}{R},$$

where n = number of revolutions; V = velocity due to fall; R = extreme radius; the useful effect still not differing notably from the maximum. 4. That they work at very considerable depths under water, the relation of useful to theoretical effect not being thereby much diminished.

On producing True Planes or Surfaces on Metals. *By Mr.* JOSEPH WHITWORTH.

Surface plates were exhibited, of which, if one be put upon the other, it will float, until by its weight it has excluded some of the air, when the two will adhere together with considerable force. These surfaces were got up without grinding. The only operations performed upon them were those of planing, filing, and scraping. Practically, the excellence of a surface consists in the number and equal distribution of the bearing points. But if a ground surface be carefully examined, the bearing points will be generally found lying together in irregular masses, with extensive cavities intervening. The cause of this irregularity is in the unmanageable nature of the process. The action of the grinding powder is under no control. There are no means for securing its equal diffusion, or for modifying its application, with reference to the particular condition of different parts of the surface; the practical result is, that the mechanic neglects the proper use of the file, knowing that grinding will follow, to efface all evidence either of care or neglect. In various departments of the arts and manufactures, the want of improvement in this respect is already felt. The valves of steam-engines, for example, the tables of printing presses, stereotype plates, slides of all kinds, require a degree of truth much superior to that they now possess, for want of which there is great waste in time, in steam power, in wear and tear, and, above all, in skill misapplied. The improvements so much to be desired will follow upon the discontinuance of grinding. The surface plate and the scraping tool will then come into use, and a new field will be opened to the skill of the mechanic. Supposing him to be provided with a true surface plate, he will find no difficulty, after a little practice, in bringing up his work to the required nicety. For this purpose he will find it advantageous to employ a scraping tool made from a three-sided file, and carefully sharpened on a Turkey stone, the use of which must be frequently repeated. A light colouring matter, such as red chalk and oil, being spread over the surface plate, and the work in hand applied thereto, friction will cause the prominent places to be marked, which will instruct the experienced mechanic where and how to operate to the greatest advantage.

On the Œconomy of Railways in respect of Gradients. By Mr. VIGNOLES.

Looking to the great cost of railways, the author had turned his attention to a comparison of the result of the working of railways, with the price paid for various degrees of perfection. On an average, the hitherto ascertained cost of the principal lines might be divided thus :—

Land	10	per cent.
Stations and carrying establishment	20	"
Management	10	"
Iron..	10	"
Works of construction proper	50	"
	100	

These items differed considerably in various railways, and in general it might be said that the works of construction constituted one-half of the whole first cost. Mr. Vignoles stated that he had analysed railway expenses of working, and had reduced them to a mileage,—that is, the average expense per mile, per train, as deduced from several years' experience, and observations of various railways under different circumstances, and with greatly different gradients, some of which lines were enumerated. The result on passenger and light traffic lines was, that the total deduction for expenditure from gross receipts was 3*s*. per mile per train; 2*s*. 6*d*. being the least, and 3*s*. 4*d*. the highest; and that this average seemed to hold good, *irrespective of gradients or curves.* Particular lines might, from local circumstances, differ in detail, but he was satisfied that the following was a fair average approximation :—

	s.	*d.*
Daily cost of locomotive power and repairs........................	1	6
Annual depreciation, sinking fund, and interest on stock, tools, shops, and establishment	0	6
Daily and annual cost in carriage department......................	0	4
Government duty, office expenses, police, clerks, guards, management, and maintenance of railway	0	8
	3	0

It was not found practicable to distinguish the additional expense, if any, arising from curves or gradients ; but as three-fourths of railway expenses were quite independent of these curves, such addition must be small ; especially as, on the North Union Railway, a line which had 5 miles out of 22 in gradients of 1 in 100, or nearly 53 feet per mile, tne total expenses were less than on the Grand Junction Railway, and several other lines.

Mr. Vignoles then proceeded to illustrate, by diagrams, the mode in which the œconomy might be made in the works of construction, on what he called the *first system*, by the occasional introduction of inclines of 50 and even 60 feet per mile, if not of too great a length ; and again, on the *second system*, by introducing entire series of severe gradients, such as those of 30, 35, and 40 feet.

On the first system he had executed the North Union Railway ;

and had also thus designed all the government railways to the south and west of England. On the second system was the Bolton and Manchester Railway, by the late Mr. Nimmo, Mr. Macneill's government railway lines to the north districts of Ireland; and that engineer had lately altered the Dublin and Kilkenny, and the Dublin and Drogheda Railways, from better but more expensive gradients, to those on the second system; and Mr. Vignoles was about to apply it to the Dublin and Kingstown Railway; and he had set out the whole extent of the Sheffield and Manchester Railway, for 40 miles, on an average gradient of nearly 40 feet per mile, mixed with occasional inclinations of 1 in 100, and with curves of one-third mile radius. Mr. Giles had also adopted the same system on the first ten miles eastward of the Newcastle and Carlisle Railway.

Mr. Vignoles went on to state, that on either one or both of these systems, introduced as might be considered most advantageous by the directing engineer, lines of railway might be laid out so as not to exceed 10,000*l.* per mile, being particularly applicable where fertile, populous, and manufacturing districts, or the metropolis, with the extremes of the empire, had to be connected through difficult and unproductive districts. When a continued stream of heavy traffic justified the expense, Mr. Vignoles saw no reason to vary from the general rules adopted hitherto by engineers for laying out railways, or from his own former opinions and practice. But it was forced on him by daily experience, that, to accommodate the public convenience, the Post Office arrangements, and business in general, it was scarcely once in twenty times that a locomotive engine went out with more than half its load, and in general the engines were only worked up to two-fifths of their full power: he was, therefore, conclusively of opinion, that it was much cheaper to put on additional engines on extraordinary occasions; and on such principles railways should be constructed through the more remote parts of the country, so as to be made in the cheapest possible manner. The possession of all the *profitable* lines of railway by private companies, was likely to throw on the government the *onus* of constructing their lines through such districts, in which case œconomy was desirable: or, if not to be constructed by the government, then was œconomy still more important; for Scotland, Ireland, Wales, and the western and eastern parts of England would be deficient in railways, until some such system as those now promulgated could be brought to bear in the laying out lines of internal communication.

On Extinguishing Fire in Steam Vessels. By Mr. WALLACE.

Mr. Wallace proposes to effect this by steam itself. The plan has been some time before the public, and many successful experiments made in the presence of scientific persons. Among the most important was the following, made on board the *Leven* steam-boat:—On the cabin floor, a space of ten feet by fourteen was covered with wet sand, on which was laid iron plates, and on these a fire was kindled with

about $4\frac{1}{2}$ cwt. of very combustible materials, such as tar barrels, &c. A hose thirty-four feet long, two and a half inches in diameter, extended from the boiler of the engine to the cabin, and when the fire had been sufficiently kindled, so that the panes of glass in the windows of the cabin began to crack by the heat, the steam was let in, and the doors of the cabin shut. The fire was extinguished in about four minutes. Several trials were made, and all with like success. On another trial, a metal pipe of a greater diameter than the hose was connected with the steam-boiler, and extended into the cabin. A small square hatch was cut in the deck immediately above the cabin, and through this opening were lowered down into the cabin two moveable grates, each containing a blazing fire, well kindled, and about 1 cwt. of coals. The hatch on the deck and cabin doors were then shut, and the steam let in, and in fifteen minutes the small hatch was opened, and one of the grates hoisted up, when the whole mass of coal and cinders, which had before formed a powerful fire, were found to be completely extinguished. This experiment was repeated twice with equal success.

On Timber Bridges of a large size, in special reference to Railways. By Mr. VIGNOLES.

Mr. Vignoles took a rapid view of the history of timber bridges, tracing their first erection in Germany, then through the United States of America, and back to Great Britain. He also described the difference between the principles of large bridges constructed with baulks and half-baulks, and of timber arches formed of layers of plank laid over each other, and fastened securely together, and with felt or other means, to make the joints and beds wholly impervious to water. Mr. Vignoles stated, that the first bridge on this principle in Great Britain had been erected at some place in Scotland, by an ingenious mechanic of that country, whose name he regretted not to be able to state. This was many years since. The principle had been also made known, particularly of late years, by the timber viaducts erected under the direction of Messrs. Green and Son, of Newcastle-on-Tyne, who had built several, and had designed more; and Mr. Nicholas Wood, of Killingworth, was at this time erecting, for the Duke of Buccleugh, a timber viaduct, of great height, and with large openings. Mr. Vignoles then explained the peculiar applicability of timber bridges or viaducts to the passage of deep ravines, so often met with in hilly and mountainous districts, illustrating his remarks by diagrams. Instances had occurred and might occur, where the whole of a line of railway, otherwise highly desirable, would have to be abandoned, unless some œconomical construction were devised to surmount the difficulty: and here the timber viaduct would most advantageously be introduced, since many feet additional height in the level of the railway would add but little to the expense. In reference to the expense, he stated, that it was chiefly when extraordinary height and either one arch of great span were required, or where a series of arches, of large openings, were

wanted or could be introduced, that the timber viaducts were the most œconomical. In ordinary heights of 50 or 60 feet, and with arches of less span than 100 feet, and particularly in countries presenting facilities for construction of stone, these latter would be undoubtedly preferable; but when the height of the construction became great, the great expense for the centering for arches of masonry, and the multiplication of the number of piers, in order to keep the span of the arches to a moderate size, greatly increased the expense, and threw the balance vastly in favour of the timber. Mr. Vignoles instanced the Ribble Viaduct on the North Union Railway, which was about 50 feet high, with five large arches, of 120 feet span, and had cost 60*l.* per lineal foot; whereas, in another place, a timber viaduct, of 140 feet high in the centre, and averaging 100 feet high, with arches of 130 feet span, and extending for a length of nearly 2000 feet, was proposed, which would not exceed in price 20*l.* per lineal foot, the breadth of roadway being, in both cases, 28 feet for a double line of rails. Mr. Vignoles stated, that in extending lines of railway through the west of England to the packet stations, through the mountains of Wales for a communication between London and Dublin, and through many parts of Ireland, along the lines laid out by him for the Government Railway Commissioners, the timber viaducts would, from their cheapness, enable the works to be entered upon, which the great cost of stone would quite forbid.

On the Safety Rotation Railway. By Mr. HAWKINS.

Mr. Hawkins exhibited a model of a railway and carriage, recently patented by Mr. Rangeley under the above title. It is an inversion of the ordinary construction, inasmuch as wheels are made to revolve on fixed bearings, placed in two parallel lines along the road; and the carriage, without wheels, is built upon a pair of running rails, carried along upon the peripheries of the train of wheels kept in revolution by steam-engines fixed at every mile or two of the road. It is intended to have the wheels three feet diameter, and three feet apart, which will give 1760 wheels on a mile. They are to be driven by a succession of endless bands, one band in every case passing around two pullies attached to every two contiguous wheels. The carriages are designed to hold forty passengers each, with their luggage; the whole, including the carriage, not to exceed five tons; the running rails always to bear on eight or ten wheels, so that no wheel shall have to support more than about ten or twelve hundred weight. The wheels, therefore, need not weigh more than half a hundred weight each, to be sufficiently strong for supporting the carriage. It is found by experiment, that three ounces suspended from the periphery of such a wheel causes it to revolve. Any weight that sets a wheel in motion, will, if continued, cause the same to revolve with accelerated velocity, until the resistance of the atmosphere becomes equal to the accumulated force, after which a steady speed will be kept up. It is inferred from observation, that the wheels driven with a continued

force of three ounces each, would acquire a constant speed of about thirty miles an hour. It is also ascertained from experiment, that eight pounds would draw a ton weight on four three-feet wheels running on level rails, and thus that a force of forty pounds would draw the carriage. The following table is constructed from data, by which it is found that seventeen-horse power of steam-engine is required to turn each mile of wheels, and two-horse power to drive each carriage. The power to turn the wheels is neither increased by additional carriages nor by acclivities, each carriage added taking only two horse power more to carry it along upon a level; and an acclivity of 1 in 180 doubling, 1 in 90 quadrupling, and 1 in 45 octupling only the tractive force, without in any case requiring more than the seventeen-horse power to turn the wheels.

Carriages every 2 Minutes.	PASSENGERS.		HORSE POWER. Per Mile in 2 Minutes.			
	Every 2 Minutes.	In 12 Hours.	On a Level.	Up 1 in 180.	Up 1 in 90.	Up 1 in 45.
1	40	14,400	19	21	25	33
2	80	28,800	21	25	33	49
3	120	43,200	23	29	41	65
4	160	57,600	25	33	49	81
5	200	72,000	27	37	57	97

On Timber Bridges, with reference to their Application to the œconomical construction of Railways. By Mr. MITCHELL.

About twelve years ago he had erected a bridge across the Spey, consisting of an arch of 100 feet span; another about six years since of two arches of 100 feet span, with stone abutments and piers; a third across the Dee, of five arches of 75 feet span, with timber piers; besides a number of others of smaller dimensions. Œconomy was the chief object in building bridges of this material. It was found they were one-third less expensive than stone; that across the Dee, with timber piers, less than half. The period of duration he found to be from thirty to forty years; the accumulated value of the staving being more than equivalent to rebuilding the structure. In his opinion, viaducts of this material might be beneficially applied in the construction of railways, of course being suitably constructed to resist the violent action and heavy weights of railway trains.

Mr. Taylor mentioned that he had that morning received a letter from Mr. Enys, stating that Commissioners from the Dutch government had visited Cornwall, to ascertain the duty done by the Cornish

engines. Several experiments had been made at their request, and the following was the result:—

		Feet stroke.	Lifted one foot.
Wheal Vor, Borlase's engine	80 in. single	8·0	123,300,593lbs.
Fowey Consols, Austin's	80 „	9·0	122,731,766
Wheal Darlington engine	80 „	8·0	78,257,675
Charlestown United Mines	50 „	7·5	55,912,392
Ditto Stamping engine	32 „	lifting 66 stamps	60,525,000
Wheal Vor, ditto	36 dble.	lifting 72 stamps	50,085,000

On the Application of Native Alloy for Compass Pivots. *By Capt.* E. J. Johnson, *R.N.*

Among those portions of a ship's compass which most affect its working, are the pivots and caps on which the needle and card traverse, and which, like the balance of a chronometer (but of far more importance to the practical navigator), should not only be fitted with the most scrupulous attention to accuracy, but be made of materials capable of maintaining a given form under the trials to which such instruments are necessarily exposed. Having examined a great variety of compasses which had been used at sea, wherein Captain Johnson noticed that their pivots were generally injured, and often by rust, he searched numerous records of experiments for its prevention, and for improving the quality of steel in other respects, by means of alloys of platinum, palladium, silver, &c. (he alluded particularly to the experiments of Dr. Faraday and Mr. Stoddart); and Mr. Pepys having obligingly supplied Captain Johnson with specimens of similar kinds of steel to those used by them, these examples, together with pivots made of the ordinary kind of steel, and hardened and tempered in the manner recommended by eminent instrument makers, were placed in a frame for experiment; and to these again Captain Johnson added certain contrivances of his own, such as rubbing a steel pivot with sal-ammoniac, then dipping it into zinc in a state of fusion, and afterwards changing the extreme point. Some specimens he coated with a mixture of powdered zinc, oil of tar, and turpentine; and others again were set in zinc pillars, having small zinc caps, through which the extreme point of the pivot protruded after the manner of black-lead through pencil tubes. The whole of the specimens were then placed in a cellar, occasionally exposed to the open air, examined from time to time during more than half a year, and their several states, as respected oxidation, duly registered. Without going into the details of this register, the general result was, that not any of the kinds of steel pivots used in this trial, except such as were coated with zinc, remained free from rust, while the pivot made of the "native alloy" which is found with platinum, completely retained its brilliancy. Captain Johnson then applied a more severe test to this singular substance, first, by placing sulphuric acid, and then nitro-muriatic acid upon it; but even under this trial he could not observe that any change had been effected, although the blade of a penknife, subjected to a similar process, was rusted to the

centre. Having enumerated the facts respecting the trials to which he had subjected this curious material, Captain Johnson stated the conclusion that he had come to, namely, that it is sufficiently tough not to break, and hard enough not to bend, under the trials to which it would be *fairly* exposed; and that being alike free from magnetic properties and liability to oxidation from exposure to the atmosphere, it possesses the requisite qualities for the pivot of the mariner's compass; and he could not but anticipate that, when fitted with a ruby cap to correspond, it would be found greatly to improve the working. Besides the application of this substance for compass pivots, Captain Johnson stated that it might probably be found advantageous for other instruments, and especially for the points of the axes of the dipping needles fitted, on Mr. Fox's plan, for use on board ship.

On the Fan-Blast as applied to Furnaces. By Mr. FAIRBAIRN.

In explaining the methods to be pursued in adapting furnaces to the fan-blast, Mr. Fairbairn observed, that it was well known that its application to the cupola for melting pig-iron was attended with the most complete success; and the object of the present inquiry was to determine how far the same mode of blowing was applicable to furnaces on a large scale, for the purpose of smelting ores. Objections had been made to Mr. Fairbairn's plan, on account of the very low pressure at which the air is introduced into the furnace, and its insufficiency to force it through a mass of material such as is contained in the furnaces of this country, and which is from thirty to forty feet in depth. To these objections Mr. Fairbairn replied, that the same had been urged against the introduction of the fan-blast to the cupola; that, in his opinion, its efficiency was as the quantity discharged, and not the pressure, which regulated the passage of the air from the "twyres" to the top of the furnace. The fan-blast, when supplied with large apertures into the furnace, would, in his opinion, increase the process of calcination, effect a more equable temperature, and produce a superior quality of metal. It appeared, therefore, of importance that the experiment should be made; and Mr. Fairbairn offered to superintend its introduction, provided the proprietors of the numerous works in this country agreed with him in opinion, that the process would be advantageous both as regards expense, and the improved quality of the metal produced.

On the Combustion of Coal, and the Prevention of the Generation of Smoke in Furnaces. By Mr. WILLIAMS.

Mr. Williams observed, that in treating on steam and the steam-engine, the subject divides itself into the following heads:—1st, the management of *fuel* in the generation of *heat*; 2nd, the management of *heat* in the generation of *steam*; 3rd, the management of *steam* in the generation of *fuel*. The first belongs to the *furnace*, the second

to the *boiler*, and the third to the *engine*. The main constituents of coal are carbon and bitumen: the former is convertible, in the *solid* state, to the purpose of generating heat; the latter, in the *gaseous* state alone, and to this latter is referable all that assumes the character of *flame*. The greater part of the practicable œconomy in the use of coal being connected with the combustion of the gases, this division of the subject is peculiarly important. Having explained the nature of combustion, Mr. Williams went on to show that all depended on bringing the combustible and the air into contact in the proper quantities, of the proper quality, and at the proper time, the proper place, and the proper temperature. The conditions requiring attention were, 1st, the quantity; 2nd, the quality of the air admitted; 3rd, the effecting their incorporation or diffusion; 4th, the time required for the diffusion; and 5th, the place in the furnace where this should take place.

Mr. Williams exhibited several diagrams, representing the several processes connected with the combustion of a single atom of coal-gas or carburetted hydrogen, and also of bodies or masses of such gas. The essential difference between the ordinary combustion of this gas in combination with atmospheric air, and that resorted to by Mr. Gurney in combination with pure oxygen, in what is called the Bude light, was then explained. By these diagrams it was shown, 1st, what was the precise quantity of air which the combustion of gas demanded; 2nd, the degree or kind of mixture which combustion required; and 3rd, that the unavoidable want of time in the furnace to effect this degree of diffusion was the main impediment to perfect combustion, and the cause of the generation of smoke.

From the consideration of these details, the inference followed, that smoke, once generated in the furnace, cannot be burned—that, in fact, smoke thus once generated became a new fuel, demanding all the conditions of other fuels. Mr. Williams dwelt much on the chemical error of supposing that smoke or gas can be consumed by bringing it into contact or connexion with a mass of incandescent fuel on the bars of a furnace; that, in fact, this imaginary point of incandescence, or the contact with any combustible body at the temperature of incandescence, was peculiarly to be avoided, instead of being, as hitherto, sought for; and hence the failure of all those efforts to prevent or consume smoke. The great evil, then, of the present furnaces, was their construction, which did not admit the necessary extent of time (or its equivalent), time being essential to effect the perfect diffusion of mixture of the gas. Mr. Williams then proceeded to show, that unless some compensating power or means be obtained, and practically and œconomically applied, we can never arrive at full combustion, or prevent the formation of smoke. This compensating power was shown to be obtainable by means of surface, and was well exemplified in the blowpipe; the remedy, then, for the want of time in the furnaces, may be met, by introducing the air in the most effective situation, by means of numerous small jets. Mr. Williams submitted the primary law to be this, viz. that no larger portions of air, that is, no greater number of atoms of air, should be introduced into any one locality than can be

absorbed and chemically combined with the atoms of the gas with which they respectively come into contact. Again, that the effecting, by means of this extended surface, this necessary diffusion was the main condition which required attention, and not that of temperature. Mr. Williams then exhibited the diagram of a boiler to be constructed on the above principles, and stated that he had an experimental boiler at work, which fully proved the accuracy of the principle.

Experimental Inquiry into the Strength of Iron with respect to its Application as a substitute for Wood in Ship-building. By Mr. FAIRBAIRN.

The number of vessels which of late years have been made entirely of iron, and the probability of the greatly extended use of this metal in ship-building, render it desirable to attain additional knowledge to that we possess upon its resistance to the strains to which it is subjected in this new application to the purposes above stated. To meet the requirements for this purpose, the following series of experiments have been undertaken, and in a great measure completed:—1st. A series of experiments on the strength of plates of iron, as regards a direct tensile strain, both in direction of the fibre and across it. 2nd. On the strength of the joints in plates riveted together, and on the best modes of riveting. 3rd. On the strength of the various forms of ribs or frames used in ship-building, whether wholly composed of iron or of iron and wood. 4th. On the resistance of plates to compression and concussion, and on the power necessary to burst them. The experiments have been superintended by Mr. Hodgkinson, to whom Mr. Fairbairn acknowledges himself indebted for many of the results in this research.

On Strength of Iron Plates.—In the experiments all the plates were of uniform thickness; their ends had plates riveted to them on both sides, with holes bored through them perpendicular to the plate, in order that they might be connected by both, with shackles to tear them asunder in the middle, which was made narrower than the rest for that purpose. The results were as follows:

Mean breaking weights in tons per square inch, when drawn in the direction of the fibre:—

		Tons.	
Yorkshire	plates ...	25·77	Mean 22·52 tons.
Ditto	ditto ...	22·76	
Derbyshire	ditto ...	21·68	
Shropshire	ditto ...	22·83	
Staffordshire	ditto ...	19·56	

Mean breaking weights in tons per square inch, when drawn across the fibre:—

Yorkshire	plates ...	27·49	Mean 23·04 tons.
Ditto	ditto ...	26·04	
Derbyshire	ditto ...	18·65	
Shropshire	ditto ...	22·00	
Staffordshire	ditto ...	21·01	

The foregoing experiments show that there is little difference in the strength of iron plates, whether drawn in the direction of the fibre or across it. Mr. Fairbairn then gave the results of a long series of experiments on the strength of riveted plates. The same description of plates were here used as in the previous experiments; they were, however, made wider than the former plates, in order that they might contain (after the rivet-holes were punched out) the same area of cross section as the previous ones.

Mean breaking weights in lbs. from four plates of equal section, riveted by a single row of rivets:—

$$\left.\begin{array}{r}20,127\\16,107\\18,982\\19,147\end{array}\right\}\text{Mean } 18,590 \text{ lbs.}$$

The mean breaking weights in lbs. from four plates of equal sections to the last, but united with a double row of rivets:—

$$\left.\begin{array}{r}22,699\\23,371\\20,059\\22,902\end{array}\right\}\text{Mean } 22,258 \text{ lbs.}$$

Whence the strength of single to double riveting is as 18,590 : 22,258. But from a comparison of the results taken from the whole experiments, the strength derived from the double riveted joints was to that of the single as 25,030 : 18,591, or as 1000 to 742. Comparing the strength of plates alone with that of double and single riveted joints, Mr. Fairbairn gave their relative values as under:—

For the strength of the plate	100
For that of double riveted joints	70
And for the single riveted joints	56

Hence the strength of plates to that of the joints as the respective numbers 100, 70 and 56. Mr. Fairbairn then gave a table containing the dimensions and distances of rivets for joining together different thicknesses of plates.

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*Experimental Researches into the Strength of Pillars of Cast Iron, and other Materials**. *By* EATON HODGKINSON, *Esq.*

When it is considered to what extent pillars of iron and of timber are used for the support of buildings, and reflect that there are no satisfactory rules by which to measure the strength of pillars, it will appear to be a matter of great importance to obtain rules by means of experiment, and, if possible, the laws on which they depend.

A feeling of this kind, heightened by the remarks of Dr. Robison, in his Mechanical Philosophy, vol. i., and the strongly-expressed opinion of our want of such knowledge by Mr. Barlow, led me to wish to undertake the inquiry. I mentioned the matter, therefore, to my friend

* This communication is an abstract of a paper read before the Royal Society a short time previous to the meeting.

Mr. Fairbairn, who, with that liberality which I have experienced from him on former occasions, at once put every means of a full investigation into my hands. He expressed a wish that I should extend the inquiry to pillars of various kinds, ancient as well as modern, and leave no part of the subject I undertook till I had obtained full satisfaction upon it from experiment. Thus freed from restraint, I endeavoured to forget the expense I put my friend to, in my wish to acquire the requisite information.

The experiments are contained in thirteen tables, as below.

Cast Iron.

Table 1.	Solid uniform cylindrical pillars, with rounded ends	55
„ 2.	Ditto ditto with flat ends	51
„ 3.	Solid uniform square pillars, with rounded ends	7
„ 4.	Solid uniform cylindrical pillars, with discs	12
„ 5.	Ditto ditto with ends rounded, rounded and flat, and both ends flat	23
„ 6.	Solid cylindrical pillars, enlarged middle, rounded ends	7
„ 7.	Ditto ditto discs on ends	4
„ 8.	Hollow uniform cylinders, rounded ends	19
„ 9.	Hollow uniform cylinders, flat ends	11
„ 10.	Short hollow uniform pillars, flat ends	13
„ 11.	Pillars, hollow and solid, of various forms, and different modes of fixing	10
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The pillars, during the experiments, were placed vertically, resting upon a flat, smooth plate of hardened steel, laid upon a cast-iron shelf, made very strong, and lying horizontal. The pressure was communicated to the upper end of the pillar by means of a strong lever acting upon a bolt of hardened steel, $2\frac{1}{2}$ inches diameter, and about a foot long, kept vertical by being made to pass through a hole bored in a deep mass of cast-iron; the hole being so turned as just to let the bolt slide easily through without lateral play. The top of the bolt was hemispherical, that the pressure from the lever might act through its axis; and the bottom was turned flat to rest upon the pillar. The bottom of this bolt, and the shelf on which the pillar stood, were necessarily kept parallel to each other; for the mass through which the bolt passed, and that on which the shelf rested, were parts of the same large case of iron, cast in one piece, and so formed as to admit shelves at various heights for breaking pillars of different lengths. The case had three of its four sides closed; circular apertures were, however, made through them, that the experimenter might observe the pillar without danger.

Experiments.

With a view to develope the laws connecting the strength of cast-iron pillars with their dimensions, they were broken of various lengths, from five feet to one inch, and the diameters varied from half an inch to two inches, in solid pillars; and in hollow ones the length was increased to seven feet six inches, and the diameter to $3\frac{1}{2}$ inches. My first object was to supply the deficiencies of Euler's theory of the strength of pillars *, if it should appear capable of being rendered practically useful; and, if not, to endeavour to adapt the experiments so as to lead to useful results. As the results of the experiments were intended to be compared together, it was desirable that all the pillars of cast iron should be from one species of metal; and the description chosen was a Yorkshire iron, the Low Moor, No. 3. The pillars were mostly made cylindrical, as that seemed a more convenient form in experiments of this kind than the square; for square pillars generally break anglewise. The experiments in the first table were made on solid uniform pillars, rounded at the ends, that the force might pass along the axis; and the metal was cast in dry sand, to obtain, as far as possible, uniformity in its texture. In the second table the pillars were uniform and cylindrical, as before, but had their ends flat and at right angles to the axis. In this table the variety of the lengths and diameters of the pillars was considerable; and in the lengths it was greater than in the former table. The pillars were from the same models as before, but were cast in green (moist) sand.

Results from the 1st and 2nd Tables.

1st. In all long pillars of the same dimensions, the resistance to crushing by flexure is about three times greater when the ends of the pillars are flat, than when they are rounded.

2nd. The strength of a pillar, with one end round and the other flat, is the arithmetical mean between that of a pillar of the same dimensions with both ends round, and one with both ends flat. Thus, of three cylindrical pillars, all of the same length and diameter, the first having both its ends rounded, the second with one end rounded and one flat, and the third with both ends flat, the strengths are as 1, 2, 3 nearly.

3rd. A long uniform cast-iron pillar, with its ends firmly fixed, whether by means of discs or otherwise, has the same power to resist breaking as a pillar of the same diameter, and half the length, with the ends rounded or turned so that the force would pass through the axis.

4th. The experiments in Tables 6. and 7. show that some additional strength is given to a pillar by enlarging its diameter in the middle part; this increase does not, however, appear to be more than one-seventh or one-eighth of the breaking weight.

5th. The index of the power of the diameter to which the strength of long pillars with rounded ends is proportional, is 3·76 nearly, and 3·55 in those with flat ends, as appeared from the results of a great

* Berlin Memoirs, 1757.

number of experiments; or the strength of both may be taken as the 3·6 power of the diameter nearly.

6th. In pillars of the same thickness the strength is inversely proportional to the 1·7 power of the length nearly.

Thus the strength of a solid pillar with rounded ends, the diameter of which is d, and the length l, is as $\frac{d^{3\cdot6}}{l^{1\cdot7}}$.

The absolute strengths of solid pillars, as appeared from the experiments, are nearly as below.

In pillars with rounded ends,

$$\text{Strength in tons} = 14{\cdot}9\ \frac{d^{3\cdot6}}{l^{1\cdot7}}.$$

In pillars with flat ends,

$$\text{Strength in tons} = 44{\cdot}16\ \frac{d^{3\cdot6}}{l^{1\cdot7}}.$$

In hollow pillars nearly the same laws were found to obtain; thus, if D and d be the external and internal diameters of a pillar, whose length is l, the strength of a hollow pillar, of which the ends were moveable (as in the connecting rod of a steam-engine), would be expressed by the formula below.

$$\text{Strength in tons} = 13 \times \frac{D^{3\cdot6} - d^{3\cdot6}}{l^{1\cdot7}}.$$

In solid pillars, whose ends are flat, we had from experiment as before,

$$\text{Strength in tons} = 44{\cdot}3 \times \frac{D^{3\cdot6} - d^{3\cdot6}}{l^{1\cdot7}}.$$

The formula above apply to all pillars whose length is not less than about thirty times the external diameter; for pillars shorter than this, it is necessary to have recourse to another formula, which has been investigated by the author*.

Similar Pillars.

In similar pillars, or those whose length is to the diameter in a constant proportion, the strength is nearly as the square of the diameter, or of any other linear dimension; or in other words, the strength is nearly as the area of the transverse section.

In hollow pillars, of greater diameter at one end than the other, or in the middle than at the ends (Table 11.), it was not found that any additional strength was obtained over that of cylindrical pillars.

The strength of a pillar, in the form of the connecting rod of a steam-engine, was found to be very small, perhaps not more than half the strength that the same metal would have given if cast in the form of a uniform hollow cylinder.

* In this case the formula for the strength is $\frac{b\,c}{b + \frac{3}{4}c}$, where b is the breaking weight of the pillar, as calculated according to the previous formula for long flexible pillars; and $c =$ the force which would crush a pillar of the same section without flexure.

A pillar irregularly fixed, so that the pressure would be in the direction of the diagonal, is reduced to one-third of its strength. Pillars fixed at one end and moveable at the other, as in those flat at one end and rounded at the other, break at one-third of the length from the moveable end; therefore, to economize the metal, they should be rendered stronger there than in other parts.

Long-continued Pressure on Pillars.

To determine the effect of a load laying constantly upon a pillar, Mr. Fairbairn had, at the writer's suggestion, four pillars cast, all of the same length and diameter; the first was loaded with 4 cwt., the second with 7 cwt., the third with 10 cwt., and the fourth with 13 cwt.; this last was loaded with $\frac{97}{100}$ of what had previously broken a pillar of the same dimensions, when the weight was carefully laid on without loss of time. The pillar loaded with the 13 cwt. bore the weight between five and six months, and then broke.

General Properties of Pillars.

In the pillars of wrought iron and steel, in Table 12, and in those of timber in Table 13, the same laws, with respect to rounded and flat ends, were found to obtain, as had been shown to exist in cast-iron.

Of rectangular pillars of timber, it was proved experimentally that the pillar of greatest strength of the same material is a square.

In square pillars of oak, with flat ends, the strength was expressed by this formula,

$$\text{Strength in tons} = 69 \times \frac{d^4}{l^2};$$

where d is the side of the square, and l the length, as before.

Comparative Strengths of Cast Iron, Wrought Iron, Steel and Timber.

It resulted from the experiments upon long pillars of the same dimensions, but of different materials, that if we call the strength of cast iron 1000, we shall have for wrought iron 1745, cast steel 2518, Dantzic oak 108·8, red deal 78·5.

On a Revolving Balance. By Mr. LOTHIAN.

The opposing arms of this balance are curved, being formed of two spirals, the one situated vertically over the other, and both bending round a common centre of movement, which is placed in the pale of the upper curve. The spirals diverge from each other near their origin, but approach and merge together at their extremes, and thus form one continuous curve, which is grooved on its circumference. The cords or chains which suspend the receiving scale and counterpoise act against each other in this groove—the weight of the scale, when hanging from a lengthened radiant of the upper spiral, being in equilibrio with the greater weight of the counterpoise when hanging

from a shorter radiant of the lower one. When this state of rest is disturbed by loading the scale the balance moves round, and, in the progress of its revolution, the opposite eccentricities of the spirals combine in changing the ratio of the leverage, and thus originate a self-adjusting power, by which the loads of both cords are mutually moved into equilibrium. The receiving scale thus commences with greater, and ends with less mechanical power than the counterpoise—a circumstance which is in harmony with the purpose of employing an unchanging weight to measure others both less and greater than itself; while the principle is one which concentrates the power and abridges the size of the machine. In order, however, that the total amount of adjusting power thus generally obtained may be equally drawn upon and advantageously distributed throughout the movement of the balance, a definite relation is established between the weight of the counterpoise and the rates at which the accumulating weight of the scale and the leverage of the lower spiral increase. The leverage of the upper spiral, being derived from these ascertained conditions, is made to preserve a rate of decrease which accords with the previously regulated increase in the leverage of the lower curve; while both spirals have their precise form determined by the additional consideration of the direction in which the cords exert their power on the circumference of the balance. In their calculated formation the two spirals are thus dependent on and related to each other, while together they are component parts of one continuous curve, in which the mutual and combined changes of leverage are made to follow an equable, as well as a general progressive gradation; by which means the balance is moved through equal angles by equal weights. In machines intended for weights of considerable amount, the balance is made to revolve about an axis, which is itself supported, a little above its centre, on knife-edge rests, so as to combine the movement of the revolving balance with the libration of the common one—the coincidence of a pointer from the axis with the ordinary pointer of the machine showing when the indication is practically unaffected by friction. In machines for weights of still greater magnitude, the articles to be weighed are made to act, in part, as their own counterpoise, by adopting differential curves to diminish the descending power of the scale; by which a comparatively small counterpoise is made to adjust the unsupported difference of weights greatly exceeding itself.

On a Water Filter. By Mr. Thom.

Mr. Thom described a self-cleaning filter, similar to those which have been in use on a large scale at Greenock for about thirteen, and at Paisley for three years, and which purify water, not only in which mud and other impurities are *mixed* or merely *suspended*, but which also free moss-water of its colour and taste, thereby rendering it, in both respects, similar to spring-water. The substance which produces this effect is a species of trap-rock or amygdaloid, very com-

mon on the hills above Greenock, and in other places in Scotland; and Mr. Thom was led to adopt it from having seen its effect in nature in purifying dark moss-water which filtered through it.

In forming the filters at Greenock, in 1827, Mr. Thom proved the effect of this substance, by breaking down the rock to the size of small peas and less, and mixing this with fine *sharp* sand, and then forming the filtering medium of the mixture. The fine sand is composed of quartz, reduced to powder by the action of the sea, &c. This sand keeps the filtering medium longer open than it would be without it, and is better adapted for the self-cleaning process than any other kind of sand, or than the pounded rock by itself.

The water is filtered by passing directly downwards through the media; the media are in their turn cleaned by passing the water through them upwards. On the large scale it is proper to do this once a week; but the whole process of cleaning only requires about an hour's time, and to accomplish this it is only necessary to shut and open two stop-cocks alternately, and allow the water time to carry up any impurities that may be obstructing the operation; and these being always found very near the surface, the operation is quickened by moving the sand there gently with a fine rake, *after* the upward current has continued for a few minutes. If the surface is disturbed while the current is passing downwards, it does injury by sending the impurities further down. In Greenock the filtering bed is made considerably deeper than at Paisley, the water at the latter place being naturally less impure than at the former. The Paisley filter is, therefore, much cheaper in the construction than those at Greenock; and this *one* filter, at an expense considerably under 1000*l*., produces an abundant supply of fine water for 30,000 inhabitants.

On a Smoke Protector. By Mr. WALLACE.

On an Improved Working Barrel for use in sinking Pits, &c. By MATTHIAS DUNN.

The improvement here referred to consists in attaching a branch side pipe of about one-third the diameter of the working barrel, extending from above to below the space traversed by the bucket, in which pipe is inserted a cock, whereby to regulate the discharge of water from the column above into the space below. It is peculiarly fitted to the exigencies of sinking pits, where the water is required to be kept so low in the bottom as to enable the sumping to be carried forward, and in the effecting of which air is constantly liable to be drawn into the windbore at the snoreholes, which has a tendency to destroy the equilibrium of the engine and cause great and continual damage. The cock is manœuvred by the sinkers in the bottom of the pit by means of an iron rod, letting back so much water into the space between the bucket and clack as just to drain the feeders and nothing more, and by having a constant eye to it this is found to be exactly effected.

On a Machine Regulator. By Mr. Rayners.

The Regulator has for its primary object the alteration or regulation of the velocity of any surface in rotary motion; this method of adjusting speed is presumed to be applicable to any combination of machinery where such variation is required, and it may be safely asserted that this controling power has never yet been perfectly attained. The inventors conceive the "Regulator" to have fully supplied this want.

From the earliest time of machine spinning, it has been an object to adjust, with precision, the "drag" on the bobbin, so as to be equally able to wind on its cylinder the finest yarns and rovings without injurious strain, and to give the required tension to the stronger yarns and threads. In the usual method of spinning by the water-frame or throstle, the bobbin is carried round by the action of the spindle on its interior surface, and washers of cloth, as well as other means, have been adopted to give a more effectual drag, by the friction of surfaces; viewing the practical operation of the drag as thus applied, the result will obviously be uncertain, irregular and imperfect, as the manufacture of the finer and softer yarns and rovings fully illustrates.

The Regulator affords the means of the exact adjustment of the "drag" or speed of the bobbin, by which the most delicate yarns or rovings can be taken up or laid on in successive coils as the operation proceeds. The Regulator, when well constructed, will give a most exact, minute and regular *strain*, and any *inferior quantity* or effect may be secured with the utmost facility. The change-wheel at the end of the screw places the "drag" completely at the control of the spinner.

By means of a model and sectional drawing the principle of the machine was illustrated.

On the Drainage of Railway Embankments and Slopes. By Mr. Smith.

On Timber Bridges. By Mr. Smith.

On Propelling Boats on Canals. By Mr. Smith.

Mr. Smith proposed that the steam power in the boat should drive two large wheels, of thirty feet diameter, which should bite the ground at the bottom of the canal. He exhibited a working model on this principle, which succeeded on the small scale; and he stated that he had tried it on a larger scale with the power of four men, and it had also succeeded. The wheels might be either on each side of the boat, as in the model, with a provision for a play of three or four feet, that they might accommodate themselves to inequalities at the bottom of the canal; or there might be one wheel in the centre of the boat, if constructed on the twin principle.

On Mr. Bakewell's Anglemeter. By Mr. J. Hawkins.

The instrument was exhibited and explained by Mr. Hawkins, and its use in measuring the angle of dip of the strata, joint planes, &c., pointed out.

On a New Canal Lock. By Mr. Smith, *of Deanston.*

The advantages of this invention he stated to be, that the descent in each lock would not be more than twelve to eighteen inches—that the locks were opened by the passage of the vessels—that the locks shut of themselves—that the vessels did not require to stop—and that little or no water was lost. The lock-gate is hinged at the bottom; the upper portion, which is round, floats at the level of the higher part of the water, and is pressed down by the bow of the vessel in passing, and when it has passed, rises to its former position.

On Raising Water from Low Lands. By Mr. Fairbairn.

The Commissioners for draining the Lake of Haarlem having applied to Mr. Fairbairn on the subject, he proposed a method where the water is raised by a large scoop, which rises on the descent of a weight, which weight is raised by steam power, on the Cornish principle. It is calculated to raise seventeen tons at each stroke. Mr. Fairbairn exhibited a model in illustration.

Mr. Hodgkinson exhibited Mr. Clegg's new Safety Lamp, with the protecting wire-gauze of a Davy Lamp. It is surrounded by a triangular frame with bull's-eye glasses.

On an Improved Rain Gauge. By Mr. Thom.

It consists of a cylinder two feet long and seven inches in diameter, sunk in the earth till the mouth of its funnel (which receives the rain) is on a level with the ground surrounding it. Into this cylinder is put a float, with a scale or graduated rod attached to it, which will move up or down as the water rises or falls in the cylinder. There is a thin brass bar fixed within the funnel, about half an inch under its mouth, with an aperture in the middle just large enough to allow the scale to move easily through it. The upper side of this cross bar is brought to a fine edge, so as to cut but not obstruct the drops which may alight on it. There is an aperture also in the bottom of the funnel, through which the water must pass into the cylinder, and through which also the scale must move; but this aperture requires to be made no larger than just to permit the scale to move through it freely. The cylinder is firmly fixed in a large flat stone, level with the surface of the ground; in the stone a groove is cut round the gauge to guard it from receiving rain which may fall on the stone. The adjustment to zero is performed in the usual way.

On a New Rain Gauge. By Mr. JAMES JOHNSTON.

Mr. Johnston described a new rain gauge, so constructed that the receiving funnel or orifice at which the rain enters is always kept at right angles to the falling rain. By the action of the wind on a large vane, the whole gauge is turned round on a pivot, until the front of the gauge faces the quarter from whence the wind blows; and by the action of the wind on another vane attached to the receiving funnel, the mouth of the funnel is moved from a horizontal towards a perpendicular position, according to the strength of the wind. The receiving funnel and vane attached to it are balanced with counterpoise weights, in such a manner that the wind, in moving them, has as much weight to remove from a perpendicular position, in proportion to their bulk, as it has when moving an ordinary-sized drop of rain from the same position; by this means the mouth of the gauge is kept at right angles to the falling rain.

Mr. Sanders exhibited a portrait produced from an engraving done by a machine invented by Mr. W. West of Bristol, being a combination of circular and straight line engraving.

Mr. Clarke exhibited a large Electro-Magnet.

Mr. Milne gave an account of a High-Pressure Filter for domestic purposes.

On an Improved Life-Boat. By the Rev. Dr. PATERSON.

He called it a Riddle Life-Boat, because the bottom is like a riddle. The sides of the boat consist each of a hollow elliptical tube, to be made of sheet-iron, and from this it has all its buoyancy, which is unaffected by any influx of water. This boat, he said, was light, easily propelled, and drew only a foot or two of water; and besides being used for reaching vessels in distress, or carrying passengers to steamboats, it might be itself carried as a ship's boat—to be ready for use in danger or difficult landing.

M. le Comte de Lille explained his method of laying down Wood Pavement, as exemplified at Whitehall.

On certain Improvements on Locomotive and other Engine Boilers. By Mr. HAWTHORN.

The object of this improvement is to prevent what is technically called "priming," to heat the steam on its passage to the cylinder, and

to employ return tubes, as well as direct tubes, for heating the water. The advantages are said to be, that no water is carried with the steam into the cylinder, and a saving of fuel, through the arrangement of the tubes, from 30 to 40 per cent.

On Wrought-Iron Wheels for Locomotive Engines. By Mr. Grime.

In this communication Mr. Grime detailed the construction, and discussed the advantages, of an entire wrought-iron wheel, suitable for engines, tenders, &c., for which he has obtained a patent.

Account of a Railway Wheel with Wood Tyre. By Mr. Dircks.

The construction of the wheel will be understood by imagining an ordinary spoked wheel, but with a deep-*channelled* tyre. In this channel are inserted blocks of African oak, measuring about $4 \times 3\frac{1}{2}$ inches, prepared by filling the pores with such unctuous preparations as counteract the effects of capillary attraction in regard to wet or damp. The blocks are cut so as to fit very exactly, with the grain placed vertically throughout, forming a kind of wooden tyre. There are about thirty blocks of wood round each wheel, where they are retained in their places by bolts, the two sides of the channel having corresponding holes drilled through them for this purpose; each block of wood is thus fastened by one or two bolts, which are afterwards well rivetted. After being so fitted, the wheel is put into a lathe, and turned in the ordinary manner of turning iron tyres, when it acquires all the appearance of a common railway wheel, but with an outer wooden rim, and the flange only of iron. Mr. Dircks proposes the use of either hard or soft woods, and of various chemical preparations to prevent the admission of water into the pores of the wood: he also contemplates the using of wood well compressed. A wheel was exhibited, one of a set which had been in use for two months, carrying five tons daily.

On a new Step-Rail, and Railway Carriages. By Mr. Coles.

Mr. Coles proposed to introduce friction wheels; and that, excepting the first and last carriage in the train, the carriages should run on *two* wheels. He also proposes a step-rail at the curves or bends, to have the effect of reducing them to cants. Mr. Coles described minutely the plan thus noticed, and discussed the expected advantages.

On an Improvement on the Air-Pump. By Mr. Lang.

On Safety-Valves for Steam Boilers. By Mr. GULLINE.

The author endeavoured to prove that the safety-valves at present in use are not large enough, and proposed a construction of boiler and valve, such that the whole top of the boiler should in fact be constituted a safety-valve.

On a Gas Regulator. By Mr. JAMES MILNE.

By means of this invention the length of the flames is equalized, notwithstanding the variations of pressure that occur, and a considerable saving in the consumption of gas is effected.

Mr. Alexander gave an explanation of his Electro-Magnetic Telegraph.

Mr. Dunn explained "Ponton's Electro-Magnetic Telegraph," which instrument was exhibited in the model-room.

On a New Hydraulic Apparatus. By Mr. JEFFREY.

It comprised an improvement on the ancient endless chain of buckets, which the author considers of Egyptian origin. This apparatus has hitherto never acquired the value it admits of, on account of a defect having remained in its construction, opposed to geometrical principle—the buckets which bring up the water being fixed outside instead of within the rope. The effect of this is such an acceleration of the bucket, when it is carried round the wheel at top, as causes it to overtake the water and carry much of it down again. But by placing the buckets on the centre side of the ropes, that is, within them, the bucket when passing round the wheel, being very near the centre, is much retarded, and the momentum of the water causes it to ride out of the bucket very effectually into the trough. A peculiarity in the form of the bucket also prevents the spilling of the water in cases where the motion is very slow.

Mr. Jeffreys described a fire-grate, exhibited in the model-room, which may be placed, he said, so far forwards as to be quite out of the chimney, and radiate a two-fold quantity of heat into the apartment, and yet there shall be no tendency to send smoke into the room. By an addition, in accordance with the same principle, fresh air is introduced, comfortably warmed before it enters the room.

Mr. Fairbairn described "Hall's Patent Hydraulic Belt for Raising Water."

On Warming and Ventilating Buildings. By Mr. Ritchie.

The principal object of this paper was to call the attention of architects to the construction of houses, with a view to a better provision for heating and ventilation. The author described the method adopted by Sir J. Robison, whose house is warmed by a large supply of air heated to 70°, which is allowed to issue directly into the lobby and staircase, which it heats to 60° even in the coldest weather. This heated air is allowed to enter the sitting rooms freely by concealed apertures over the doors, and the vitiated air is carried off through openings in the ceilings by separate flues in each room.

Sir John Robison stated that, with the apparatus in his house, he can keep his staircase at a temperature of from 58° to 62°, when the current of heated air was only 64° as it issued from the apparatus, and that the additional expense caused by his provision for ventilation did not exceed 20*l*.

On Dennett's Rockets for preserving Lives from Shipwreck. By Mr. Grime.

On the subject of this invention various documents were presented, and a letter was read from Captain Denham, stating that the range of these rockets exceeded that of the mortar by 100 yards, the range of the rockets being about 350 yards, while that of the mortar was but about 250.

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THE END.

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he Heart;—Report of the Dublin Committee on the Pathology of the Brain and Nervous System;—J. W. Lubbock, Esq., Account of the recent Discussions of Observations of the Tides;—Rev. Baden Powell, on determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media;—Dr. Hodgkin, on the Communication between the Arteries and Absorbents;—Prof. Phillips, Report of Experiments on Subterranean Temperature;—Prof. Hamilton, on the Validity of a Method recently proposed by George B. Jerrard, Esq., for Transforming and Resolving Equations of Elevated Degrees.

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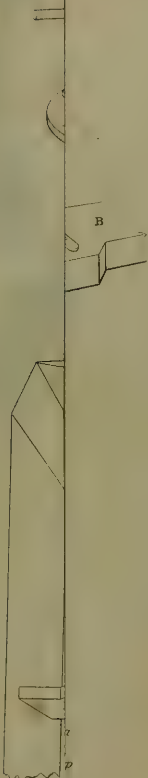
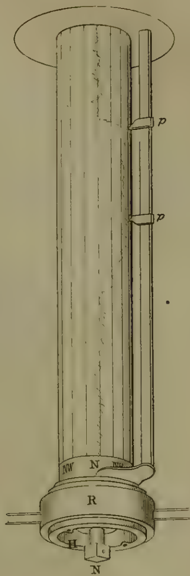


Fig. 12.



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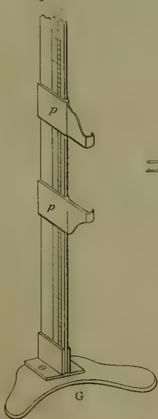

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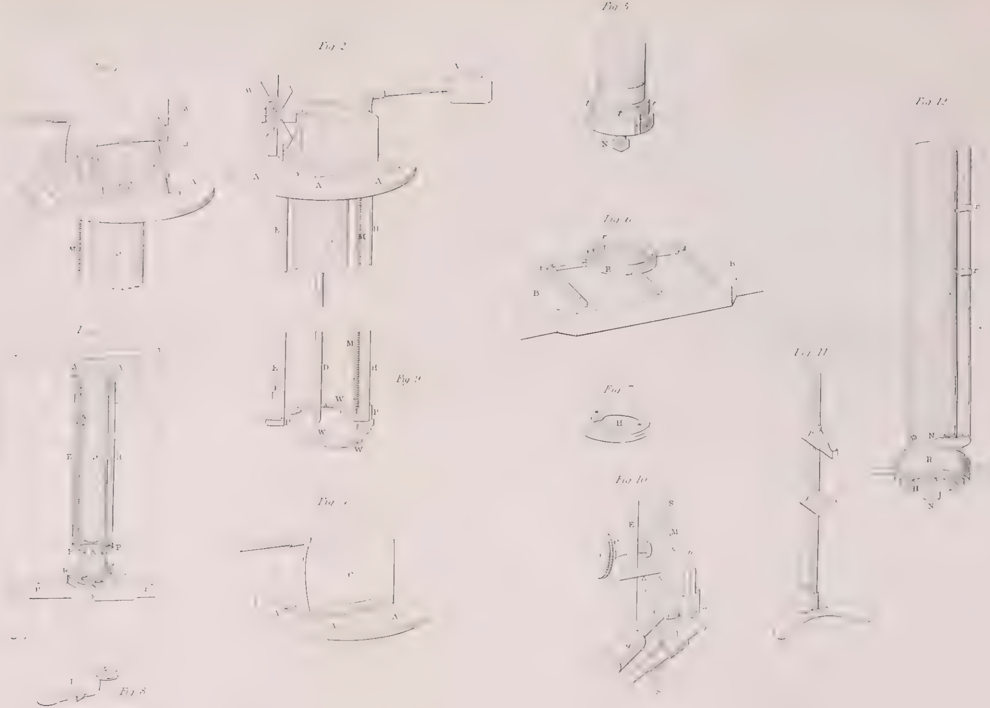

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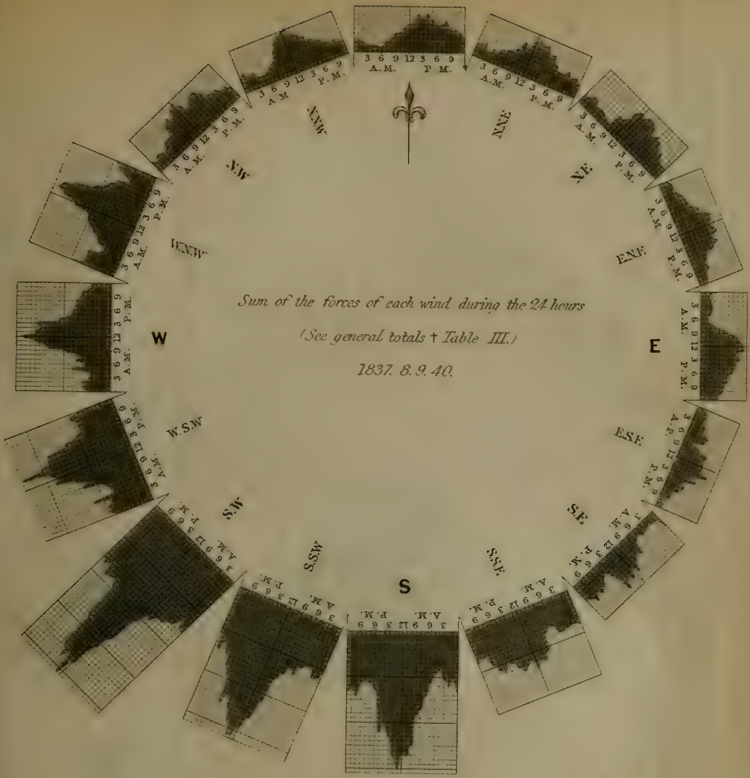
Fig. 1



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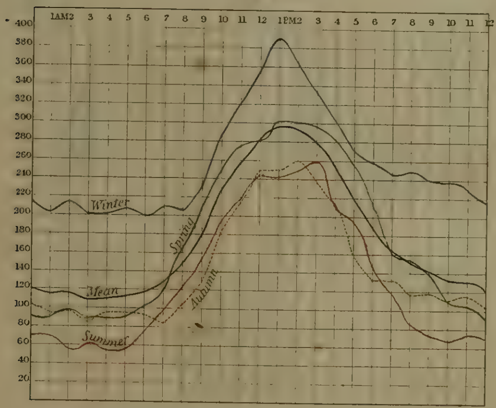

Sum of the forces of the wind during each hour of the day direction not being regarded, as given in table V.

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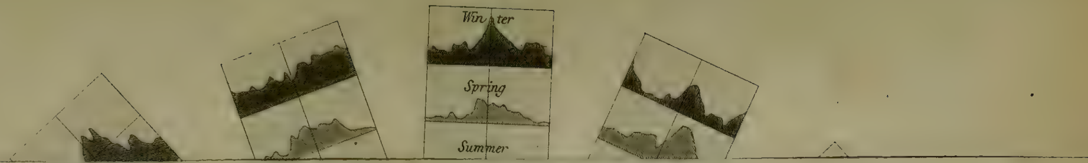
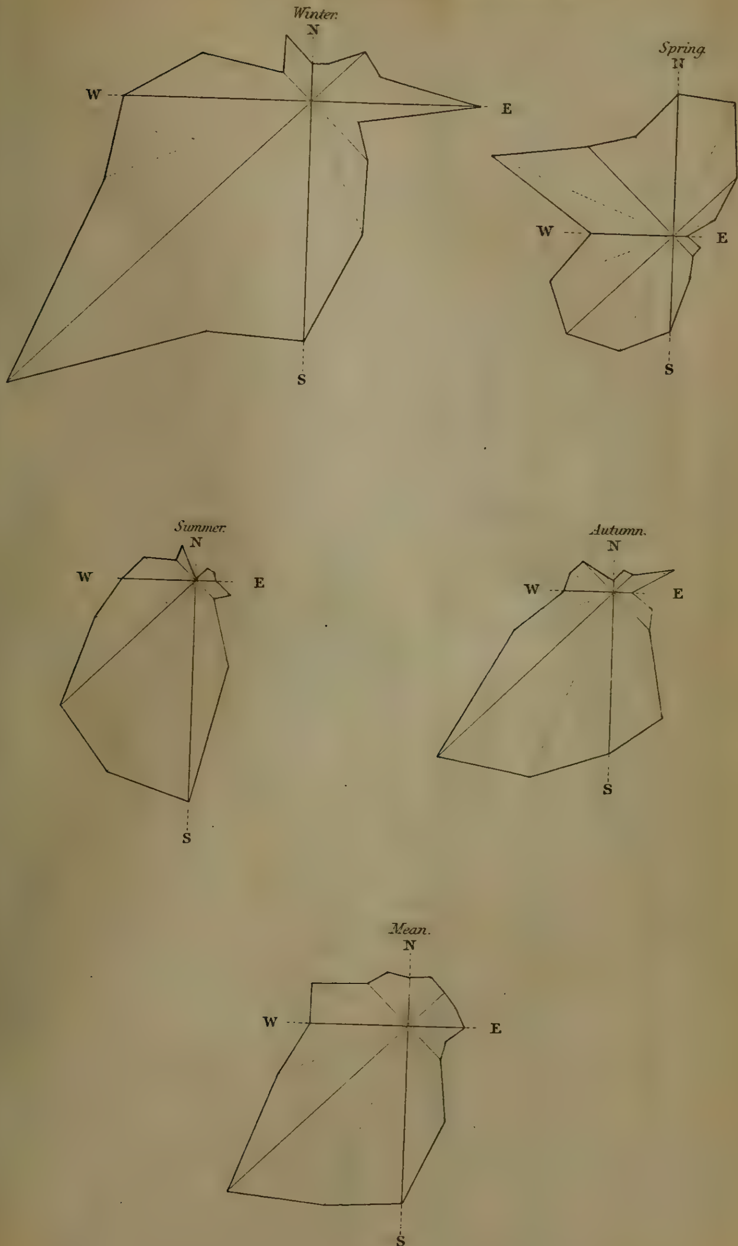

Winter
Spring
Summer

Plate 3

J. W. Lowry, Sculp.

Diagrams Showing the Comparative force and direction of the wind obtained from the Sum of the hourly means given in Table VI. Plate 4



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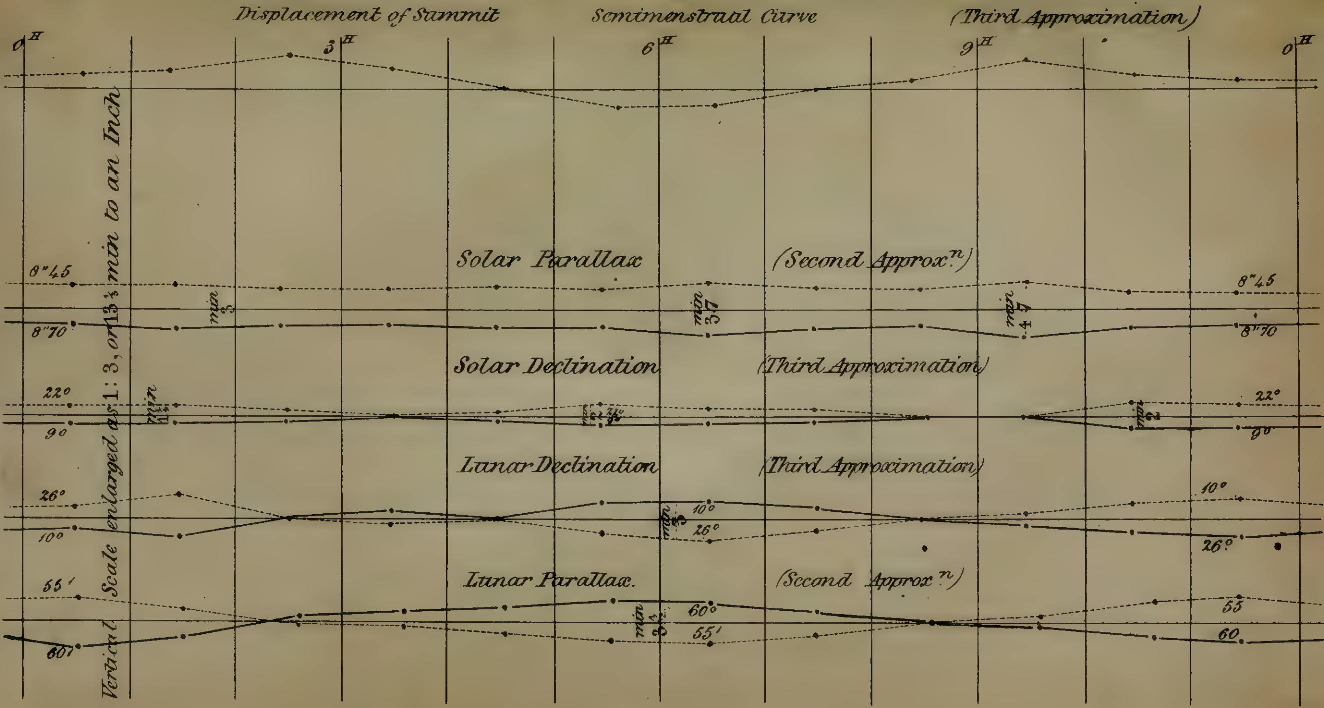

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